SPACE SHUTTLE OPERATIONS

HEARING

BEFORE THE

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SPACE SHUTTLE OPERATIONS

WEDNESDAY, DECEMBER 9, 1981

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met at 9:34 a.m. in room 235 of the Russell Senate Office Building; Hon. Harrison H. Schmitt (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR SCHMITT

Senator SCHMITT. The hearing will come to order.

The second flight of the space shuttle *Columbia,* both a spaceship and an airship, I should add, in October, established a new era, that of the reusable space vehicle. Even though all aspects of the operational phase have not been worked out, I think it is safe to say from the experience and the trends noted in the first two flights, that there is no reason to expect that the operational phase is not going to follow roughly on schedule. This was an accomplishment that has not yet been challenged by any other nation in the world, and it represents a major technological first, a series of firsts, which have enormous potential and advantages for this Nation and for the free world.

The October flight of the *Columbia* was the second in a series of four, intended to test, evaluate and verify the capabilities of this unique craft. With the fifth flight of the operational—with the fifth flight, the operational phase of the space transportation system begins. We are on the verge of having affordable, routine space flights, to serve both existing and new businesses and industry, scientific and engineering experimentation and exploration and our national defense.

Proposals for space shuttle space already exceed that which will be available in the initial stages and the potential uses are only beginning to dawn on the community, that new user community.

This potential of space has not been lost on our competitors, whether they are friendly or adversarial. The monopoly of the free world launch market which we enjoy has been breached. The French will soon conduct the fourth of four test launches of their vehicle, Ariane, and are already offering attractive financial arrangements to attract global business. In fact, it is apparent, not only in terms of launch vehicle costs, but also in the competition for new spacecraft in the world market that the French are very clearly buying in. They have decided this is the market they want,

and they are willing to subsidize at least the initial phases of capturing that market.

The Japanese are also enhancing their launch capability. Even private entrepreneurs here and in Western Europe are trying to develop inexpensive launch capabilities for the burgeoning demand which they foresee.

Now more than ever we need to insure that our space activities are both reliable and competitive in financial and technological capacity. This means a well-managed, extensive operational program.

Today we begin a series of hearings on space shuttle operations and there are a number of issues that must be addressed. These issues include our capacity for production of critical commodities which govern launch priorities scheduling, demand projection for different user sectors, relationships of the civil and defense operations and operational costs. A particular challenge is determining what should be the relative private and public sector responsibilities for operation of the space shuttle. We cannot deal with all of these issues today, nor can we assume that all of the answers are clear, but it is important that we start and that we define the envelope in which the operational activities will take place.

Our emphasis at this hearing is to hear from NASA about the plans which it has made for assuring U.S. preeminence in the operational space era. Our evaluation of the issues will be continued in future hearings, including those relative to defense operations.

We are happy today to have with us, Dr. Hans Mark, who is the Deputy Administrator of NASA.

We also will submit for the record an opening statement by Senator Howard Cannon of Nevada.

[The statement follows:]

OPENING STATEMENT BY SENATOR CANNON

Mr. Chairman, in my speech on the Senate floor on November 23, I summarized my views on the importance of maintaining our Nation's preeminence in space in the decades ahead. To save time now, I would like to submit that statement for the hearing record and limit myself to a few remarks that have a direct bearing on this morning's hearing.

We meet here today in an atmosphere dominated by the need for budgetary restraint. While that may be an uncomfortable atmosphere for many, it is compatible with my four term record in the Senate. However, I have not been reluctant to support Federal expenditures required for programs necessary to advance this Nation's needs. That has been true for national defense and to promote our economic prosperity. I believe the U.S. space program is a major contributor to meeting these needs as well as adding to our understanding of the universe.

I have long been a strong supporter of our civilian space program. I believe that the space shuttle, which recently completed its second orbital flight test, will help maintain our leadership in space in the decades ahead. It was a wise investment for our Nation's future. I recognize that there have been some problems associated with the first two orbital flight tests, but these are to be expected in a research and development program. More importantly, the problems were overcome, and the flight tests were successfully completed. I am confident that the remaining two flight tests will be as successful as the previous ones, and I am sure that the knowledge gained from these flights will make the transition to the operational use of the shuttle a successful one.

Mr. Chairman, I am very glad that you have called this hearing today, and I am looking forward to learning more about NASA's current views on how the shuttle will be used in an operational mode—the problems to be overcome, and the possibilities it will permit. Thank you.

Senator SCHMITT. I would say in addition, Dr. Mark, that I really have found it a little bit uncomfortable in trying to get NASA to discuss operations of the space shuttle. I do not understand fully why that has been such a difficult process. I think the success of the first two flights indicates that you are well on your way to having an operational vehicle and, in fact, you are merging some operations with the test program. I just hope you do not feel too uncomfortable talking about these things. As we enter this next budget cycle it is extremely important, for the Congress to be fully aware of the policy implications of the space shuttle operations and of the budget proposals that the administration may—and I underline and italicize "may" put forward.

I certainly hope that we will not see a departure from good strong policy guidance by the administration. I would hate to see the Congress having to take over that policy guidance. It is a much more difficult process over here, but I think we are willing to do that if it becomes necessary.

Dr. Mark, I believe you have a short opening statement, and then we can go to questions.

STATEMENT OF DR. HANS MARK, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY GENERAL JAMES ABRAHAMSON, ASSOCIATE ADMINISTRATOR FOR SPACE TRANSPORTATION SYSTEMS, AND DR. STANLEY WEISS, ASSOCIATE ADMINISTRATOR FOR SPACE TRANSPORTATION OPERATIONS

Dr. MARK. I appreciate the opportunity to be here to help initiate the discussions for which you have asked. I think they are entirely appropriate. As you pointed out in your statement, they are timely because of the technical success we have had with the shuttle. I am accompanied today by Dr. Stanley Weiss, Associate Administrator for Space Transportation Operations, and Gen. James Abrahamson, who is the newly installed Associate Administrator for Space Transportation Systems.

Mr. Chairman, I do not have a formal opening statement; but, I would like to make a few remarks to supplement what you have said, because I find myself in very general agreement with the positions that you have outlined.

The first two flights of *Columbia* have been enormously successful in all ways. There are successes that have to do with the overall concept of the system. That is, we have proven the concept. There have been detailed engineering successes that are equally important. Ten years ago, the concept of the reusable space vehicle was a gleam in our eye; however, this year we have proven that concept. That is probably the most important thing that has happened. As you mentioned, it was done in the second flight, because that was really the first time we have ever revised a spacecraft. I think the second, and in the long term more important aspects, are the results that we have had from the second flight of the OSTA-1 payload. This is the first time that we have flown a payload designed to do things with the shuttle. The results, I think, demonstrate what many of us have always felt to be true. That is, that in conducting experiments and operations in orbit and space, there is no

substitute for the presence of human judgment and human imagination. That has come through over and over again. I think both of these issues, the concept of reusability and the importance of people present when we are doing experiments in Earth orbit, have been triumphantly demonstrated by what we have done in the last year in the two flights of *Columbia.*

There have also been engineering successes. Despite problems in the development of the thermal protection system, it has operated much better than we expected. The backface temperatures are lower; and, I think, there is no question that eventually we will be able to get a system that weighs less than the one we have now. The engines have matured. We have a good propulsion system. What is perhaps more important is that we have the propulsion system on which a new generation of launch vehicles can be based, because both the solid boosters and the high pressure liquid oxygen and hydrogen engines are really brandnew things.

Mr. Chairman, the shuttle is a good airplane. All of the worries and the fears that we had about the flight control system, about the stability of the vehicle, and about all the things that worry test pilots have been put behind us. I have talked to the flight crews at length. The vehicle performs beautifully. It is a nice airplane. We have, in short, Mr. Chairman, what I would say is an unequivocal technical and conceptual success. What we need to look at now is the problem of turning a technical success into an operational success. It is important to understand that the two are not the same. A technical program can be made successful and then fail operationally, because various institutional or economic factors are not properly taken into account.

I have gone through the business of taking technical successes and making them operational before; and, I think, I know some of the problems. In the early 1950's I worked on the nuclear submarine program. And, I watched the problems we had in taking the *Nautilus,* which was the technical proof of concept commissioned in 1954, and turning it into the fleet of ballistic missile submarines that we started to build in the 1960's.

In the case of spacecraft, I remember the first satellites which were used for surveillance purposes, the Discoverers—you may remember those, Mr. Chairman. It was not at all certain that those vehicles would be operationally successful. If I remember correctly, we bought five; and then we thought we were going to go out of business. When the user community began to realize how well this thing worked, we started to do exactly what you have suggested that we do with the shuttle. We made batch buys, and we flew them at a heavy rate for a number of years. I mention these examples only to let you know, Mr. Chairman, that there are people around who are familiar with the problems of taking a technical success and turning it into one that is operational.

The administration has also recognized this. Last summer when we were getting ourselves organized, we initiated two large studies to look at the longer term problem of how we are going to operate our space launch vehicle system. Let me talk a little bit about these studies, because, I would say, we are about one-third of the way into them now. One study deals with the question of what kind of fleet of launch vehicles this country should have. That is a

technical study which will have a technical answer, depending on certain requirements that we have. Incidentally, these requirements include the national defense requirements. This study will simply come out with a statement of the kinds of vehicles, the payloads, the hardening requirements, and things of that kind.

The other study has to do with the institutional arrangements which are needed to conduct the future of our space program. What is the role of NASA? What is the role of the Department of Defense? What are the roles of the other civilian Federal agencies that have an interest in space? How does the private sector interact and what do we do about both collaboration and competition with people in foreign countries?

It is a rather broad charter and it is one that obviously both of these studies would involve a number of Federal agencies and Federal institutions. It is because of the interagency nature of this problem, Mr. Chairman, that the studies are being conducted under the direction of Dr. George A. Keyworth, the President's science adviser and also Director of the Science and Technology Policy Office in the White House. You can rest assured, Mr. Chairman, that NASA is participating very actively in these studies. We have a very strong representation on both of them.

I believe that in the due course, the questions that these studies are dealing with will be answered to your satisfaction. Currently, we hope to have at least a preliminary report out on both of these studies by April or May of 1982 with a final report possibly a few months later.

Senator SCHMITT. If I may interrupt, with that kind of a schedule, how do you see these studies influencing the 1983 budget decisions?

Dr. MARK. They will not influence the 1983 budget.

Senator SCHMITT. Will they be influenced by the 1983 budget decisions?

Dr. MARK. That is hard to say, sir. We recognized when we started this that we would not be able to get these studies done in time to influence the 1983 budget cycle. I am going to show you a schedule shortly, if I may.

Senator SCHMITT. The only thing that concerns me is that after a very fine effort by a transition team in these areas and related areas, we are now going to look at another year and a half before it is possible for the administration to take a coordinated view of space activities. That is going to make it very difficult on the Congress, because that means if we rely on the administration to set policy, then we are going to wait for the fiscal year 1984 budget before these issues are fully addressed; and in that time, if some of the rumors turn out to be fact that we hear about the 1983 budget, there will have been policy decisions already made through the budget process and it will be very difficult to reverse those policy decisions unless we do it over here in the 1983 cycle.

Dr. MARK. You can rest assured that on the question of funding the space shuttle program that no decisions will be made in the fiscal year 1983 budget that preclude the kinds of things that both you and I are interested in. If I may, Mr. Chairman, let me show you a chart that shows the timing——

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Senator SCHMITT. Excuse me, Dr. Mark. The point is it is not just the space shuttle that is the question of space policy. As you may also recall 10 years ago, it was not the space shuttle that was the proposal. It was an American space station in space that was the proposal. The spacelab was a tremendously capable precursor of such a station; small, but nevertheless more capable than any space station-type vehicle that has ever flown, and the shuttle was just an appendage. It was the way you got back and forth.

And what we ended up with through some extraordinary set of decisions on the part of the Nixon administration was just the shuttle with a program that was obviously underfunded, and if we had not pumped some dollars into it 2 or 3 years ago, some significant dollars, we would not be here today. It was just not possible to get to those milestones without those dollars. But nevertheless, we have made it and we have done extraordinarily well, far better than most of us thought that we could do. And again, that is a tribute to the motivation of the NASA team and the industrial team that works with it, and not necessarily to the wisdom of the budget planners in various administrations up to this time.

We also hear reports or see reports in the press that officials of OSTP are not only now saying that space station probably is not a good idea, probably not a necessary part of our future, but we are seeing that planetary science is not a necessary part of our future. DOD has continued to indicate that the space shuttle is not a high priority in their planning; Weinberger has said that on occasion. They have just centralized their own space planning efforts and it is not yet clear how influential that group will be in the higher echelons of DOD management. And I said at various times, we will try to drag the DOD, kicking and screaming, into the space age. There is a lot of kicking and so forth, not a great deal of screaming. We will just wait and see how that turns out.

And then the rumors, of course, coming out of the OMB are that we are looking at something on the order of $1 billion worth of reductions in NASA's budget, which literally will gut portions of the Space Act. Those are policy decisions being made on the backs of the budget that you are telling me now we have got to wait until the middle part of next calendar year before we are going to see what those policy decisions really are. That is going to be awfully tough to sell over here in the Congress. I hope it's going to be tough to sell in the Congress.

Dr. MARK. So do I, sir. Let me continue, if I may.

First, with respect to the DOD. As you know, I have just spent 4 years there. I understand the problems that we have. Let me talk about the DOD policy study, because that is an integral part of the study that Dr. Keyworth is heading. The DOD study is meant as an input for what will finally come out of Dr. Keyworth's effort.

Now let me talk about scheduling because I think that is important. I think the question of which budget we influence and how the policy is actually made is very important, indeed. If I might have the schedule chart. [Fig. 1] This chart shows, on the top line, that the test flights which we are conducting now—the first two flights complete, the second two flights in the first and second quarter of next year, and then the first so-called operational flight toward the end of next year or the beginning of 1983. I am very

concerned about the question of how to minimize the costs of acquiring future vehicles and how to minimize the cost of acquiring the tanks and the solid rocket boosters that go with each launch. We want to initiate ways of conducting these procurements that will be more of a production line operation than it is now. Particularly, I am very anxious to insure that the ability to continue to build Shuttles is maintained, at least until we have a feeling that we know something better. Right now we don't know of anything better.

We would like to get the fifth orbiter, as you know. If you look at the third line down, there is the schedule of Orbiter 099, then Orbiter 103, and then Orbiter 104, which is to be delivered toward the beginning of 1985. At the beginning of calendar year 1983, and this is something that we have done deliberately to be in synchronism with the fiscal year 1984 budget, we want to make a decision as to how to continue to buy the shuttle vehicles. There are some savings to be made if they were bought in blocks rather than in single vehicles. We are going to review that in as much detail as is necessary to determine the necessary fiscal conclusions.

The point I want to make is that we have approximately a year to make that decision, and that we need that year to freeze the design. I believe there will be some changes based on what we learn on the first four flights. That is one question, sir, that I would like to address in the hearing. Namely, how do we produce the hardware? There is a second question that is equally important. That is, how do we schedule the vehicle so that it meets the user requirement? Right now we have a fairly rigid scheduling policy which is really based on a scarcity of hardware, to some extent. We would like to build more flexibility into our flight schedules than there is today so that we can operate the shuttle much the way that airlines operate their fleets. Of course, the airline operations depend on extra airplanes as well as flexibility which we don't have now.

I would like to get into these questions in more detail. I have two friends with me who are very well qualified to answer them. Jim Abrahamson is, in my view, one of the most brilliant young general officers in the Air Force; and, he has just come over to help us with the shuttle program. General Abrahamson, before he took the assignment, managed the F-16 program for the Air Force which is, by all accounts, the best managed defense program we have had in a long time. It came in on schedule, on cost, and it is a good airplane. My other colleague here today is Dr. Weiss who has long experience in the space business, particularly in the business of dealing with the requirements of a very diverse and demanding user community.

What I would like to do now, Mr. Chairman, is to ask General Abrahamson and Dr. Weiss to address the questions that you have asked. And, then after that, we will be ready, of course, to answer any questions you may have. Thank you, sir.

Senator SCHMITT. That's fine. I understand you have to leave about 11, Dr. Mark?

Dr. MARK. Yes.

Senator SCHMITT. I hope that the questions can begin before you have to go.

Please continue, General.

General ABRAHAMSON. Sir, before I start with my formal briefing, since this is the first time that have testified before Congress in this new capacity, I would like to get on record by saying that as a military officer I consider it a great privilege to now be a part of the NASA team and to, in fact, have this responsibility not only for NASA and the Air Force, but for the Nation.

Senator SCHMITT. General, it is good to have you with the team. I suspect we will see a lot of you. I am not going to say that next year is going to be an easy one. That is more dependent on what decisions the administration makes than what decisions you and I make. We will, nevertheless, be able to work together and it is good to have you on board, and I wish you good luck.

General ABRAHAMSON. Thank you, sir.

Dr. Mark started with, I think, the optimistic news that STS-2 was, in fact, a very fine, very impressive second step in developing the program [fig 2].

I will briefly talk about what that means; but, I will deal with it in three areas: the production capability in which you asked a series of questions, the initiatives that we are now taking, looking ahead to a successful operational phase of the space shuttle; and finally, the area that I know you have been very vitally interested in and in fact have been providing leadership and motivation—the question of block-buy and multiyear possibilities. That is only one in a series of initiatives that we need to take to bring the cost of the operational phase down lower and lower so that it can, indeed, meet the promise that it does have.

General ABRAHAMSON. Dr. Mark commented very briefly on STS-1 and STS-2, [fig. 3], and you asked what is really the significance for the operational phase of these two particular missions. I think he summarized it extremely well; therefore, I will not comment except just on a few areas.

The astronaut reports about the exceptional flying machine I know means a lot to you and it certainly does to me as a test pilot. The thermal protection system will have a great deal of impact on the operational phase of the program. If you recall in the very beginning, there was a great deal of concern about this. We now see that it is a forgiving system because its performance was better than expected. We really feel that this removes a very large area of uncertainty as we look to recurring operations.

In terms of our major flight objectives, even though STS-2 was shorter than planned, we did in fact cover 90 percent of our priority flight objectives. This means we can go into STS-3 with confidence and without having to repeat a large number of data points. I would like to summarize by saying that the implications for operations are very positive at this time. We have two more test flights. We have an important amount of engineering data that we have to fill in; but, I feel that this is an optimistic harbinger for our operational phase.

Regarding the production capability [fig. 4], you asked what our present plans and our present capability are. Currently, if we look at the external tank, the solid rocket booster [SRB], and the external tank facility as it is presently tooled, we believe we can produce about 10 to 12 per year; however, that is not enough. Our plan

is to build, in an orderly way up, to a rate of 24 per year by 1988. That does require additional investment in tooling which is part of our present plan. We look forward optimistically to a period after the 1987 time frame, when, indeed, we will have a larger number of flights. Because we are looking for a user demand that may well exceed this, it will require additional investment and facility expansion. It does require additional investment over and above our present plan.

In regard to your final question about the external tank and about our flight rate, we had to build on the demand that Dr. Weiss will describe later. What we are building to is 24 tanks per year flights by 1988. The same kind of a picture is clearly there in the solid rocket booster itself. Currently, we feel the capability is about 8 to 10 solid rocket booster sets per year. As I indicated with the external tank, with our present plan, we will be building on the order of 24 external tanks per year in 1988. But with further investment, the facility in Utah can produce a larger number. We have not investigated the detail in either of these questions. Both contractors feel that we could perhaps double our production within the facility itself with sufficient additional investment. But, our present plan will support a flight rate of 24 by 1988.

Senator SCHMITT. You don't expect to need any new facilities to go beyond that? But you would need new investment in tooling and manufacturing capability?

General ABRAHAMSON. To go beyond that, some of the investment would have to be made in terms of the buildings. We do not think we will need new buildings, but we will have to make some modifications to the layout as well as some internal changes. Most of the additional funding will be for tooling. Certainly, new buildings are not required.

In the main engines [fig. 5], our production rate is not facility constrained. We are presently producing at a rate which is consistent with the Orbiter production at about three per year, and that rate can increase with additional funding. But in this case, the funding is not for tooling; it is for the people and the components to go into the increased production rate itself. Again, all of our flight rate planning is for flight rates of 24 out in 1988.

Senator SCHMITT. Are you not now marginal in test assets?

General ABRAHAMSON. Because we are still engaged in an important series of certification tests we are pressed in terms of test assets. But, I believe for production testing that we should not have a problem because that will unload some of those test assets. At this point in the program, I have not personally looked at the tests results in sufficient detail. I can get that answer in more detail for you, sir.

Senator SCHMITT. Could you also in that answer tell us what your options are, if you had to replace an engine in the Orbiter for some reason, based on the flight data or postflight testing?

General ABRAHAMSON. Yes, sir; we will.

Senator SCHMITT. Please tell us what the capability is and how that ripples through the system.

General ABRAHAMSON. Yes.

[The following information was subsequently received for the record:]

At the present time we have only two Full Power Level (FPL) engines to support our development and certification test program. We are utilizing a modified Rated Power Level (RPL) engine to support some limited FPL turbopump testing in our third test stand. We expect to take delivery on second FPL certification engine in late January 1982. This will provide us with FPL engines for each of our three available stands. We have scheduled the recycling of two engines to provide back up for the development engines. These engines are scheduled for delivery in July 1982 and February 1983. These assets should support the remaining development tests planned at this time.

General ABRAHAMSON. In terms of the Orbiters, Dr. Mark indicated we are all interested in being able to have a fleet that is of sufficient size to meet the demand itself. Our tooling and jig capacity has been set up to handle about one Orbiter per year. But, the tooling and jig capacity is not the primary limit as to the rate at which it can produce Orbiters. It really is how many people on the job, the ability of that force to handle these very specialized tasks, and the amount of money that can be made available for the components to feed that production line itself. Presently, we are delivering Orbiters 099 and 103 on 15-month centers, which is slightly slower than we think an optimum could be, but an acceptable rate for our present work force itself.

When Orbiter 104 delivery is made, it will be a budget decision and a work force decision. Dr. Mark indicated that there has to be a careful review of the relationship between Orbiters 104 and 105 which I will discuss when I talk about the block buy concept that we could implement.

Senator SCHMITT. You don't show any materials or long lead time component constraints here. Have they disappeared?

General ABRAHAMSON. The long-lead time constraint, I believe, is a funding constraint. We program for long-lead items at particular points in time. Actually, our experience across the Department of Defense, if I may go back to my previous job, is that many long-lead items were very, very critical. Some of them, for example, landing gear and things such as that, were up to 42 months which is a very long period of time. But those are now beginning to turn around as the overall aerospace industry is coming down.

Again, in this case, I would prefer not to give you a very specific answer since I only have an overall opinion because of my newness in the program. My overall opinion is that we have programed this in a very logical way, consistent with our funding to try to balance the funds amongst all of the demands of the program. We do not have at this point something that is sticking out of bid badly in terms of a long-lead item; however, we are currently assessing the schedule impact. But, I would like to provide that in more detail after completion of the assessment.

Senator SCHMITT. Is that 105?

General ABRAHAMSON. I will discuss that later.

Senator SCHMITT. That would also affect a decision on a batch buy.

General ABRAHAMSON. Yes, it would; that's correct.

Figure 6 shows how the Orbiter flight capability builds up. The center line shows the planned buildup relative to the deliveries of Orbiters 099, 103, and 104. There is a little variability about that capability in terms of the Orbiters. That capability really depends on how efficient we are in our turnaround as we get into the out

years. In order to increase that rate, we would have to not only be very efficient and realize some of our turnaround times, which Dr. Weiss will talk about, in terms of that planning; but, we would also have to be able to plan for some additional funds for extra tanks or to move the tank and SRB delivery effort forward. But, it could be increased in terms of Orbiter capability. It could also be decreased, if for some reason we were unable to achieve some of our turnaround planning that we really hope to have come true.

In regard to operations support, figure 7, the launch pads are important to our ability to be able to launch at a high rate when we get multiple orbiters. Therefore, the Air Force has been planning for October 1985 for Vandenberg and has supported the funds to the Congress for that kind of delivery date.

After looking at the VAFB pad in September and talking to the various contractors with General Marsh, we got a much more optimistic view of our ability to meet the October 1985 date than we had earlier in the summer. In fact, I think, we have a logical plan laid out, and unless there are some disallowances either in the congressional budget or somewhere else, that is a sound one and should lead with confidence to Vandenberg in 1985. NASA is providing a great deal of support to the Air Force to insure that that happens.

Our planning for pad B at Kennedy is September 1986, which is built into our funding plan itself. One of your specific questions was in terms of our landing sites and some of the capabilities for operating off of not only the primary landing sites, but also the contingency sites. Shown is a listing of the key items that are needed to operate there: the S-band and C-band radar, UHF voice capability, the MSBLS, and the TACAN.

Right now at the two primary sites, we have all of those capabilities. We have taken the S-band out of the Northrup Strip because it is required in Dakar for the operational phase. We felt the best use was to take it out of that contingency landing site and put it where we will need it for operations. That does not have a significant effect at all in terms of our ability to be able to land and use that site on a contingency basis. Actually, all that is really lost is some real time telemetry at the ground. We still get the developmental telemetry itself.

Senator SCHMITT. Would you leave that? You don't have as a landing site Edwards—I mean Vandenberg.

General ABRAHAMSON. It will not be there until it is planned to be consistent with the overall Vandenberg facility. That is the large runway that is part of the building plan which is planned for October 1985.

Senator SCHMITT. When you say launch pad for Vandenberg, that includes the runway?

General ABRAHAMSON. Yes, sir, in that time frame. I really drew this chart in terms of our present contingency sites for short-term operations which is why I omitted Vandenberg. There is no change that I am aware of in planning not to put a runway there.

Senator SCHMITT. What if there were further delays in the Vandenberg facility's IOC, including runway? What does that do to your second bullet chart there?

General ABRAHAMSON. In terms of our ability to operate, the big impact is that we would, in fact, lose a launch site, as opposed to a landing site. The launch site is helpful. Obviously, it is needed for all of the polar orbits and some of them will be for commercial and scientific use as well as military. I think that is an important factor.

Senator SCHMITT. Are there alternatives besides a launch at Vandenberg?

General ABRAHAMSON. I think that has to be looked at very carefully. We can go back to Edwards, but what I have not done is looked at——

Senator SCHMITT. On a return to landing site launch, RTLS-type?

General ABRAHAMSON. I would have to verify that.

[The following information was subsequently received for the record:]

A contract for construction of an Orbiter runway at VAFB, to be operational in support of the Initial Operational Capability milestone of October 1985 for the VAFB Launch and Landing Site (VAFB LLS), has been approved by the Air Force Space Division. The VAFB LLS will support launches on polar and near-polar azimuths. The VAFB runway will be the primary end-of-mission landing site and will also be the designated return-to-launch site (RTLS) and abort-once-around landing site for intact aborts.

In the event that the Orbiter runway construction at VAFB were not completed in time to support the initial launches from VAFB, the only suitable coastal landing site identified to support RTLS type abort is the point Mugu NAS, California. Early analyses show the probability of the external tank (ET) impact in an off-shore oil field for Mugu RTLS; however, risk assessment is continuing. Use of Edwards AFB for RTLS type abort would result in ET impact in the Los Angeles area. RTLS at Yuma, Arizona, would result in ET impact in Mexico.

For abort-once-around in lieu of VAFB, Edwards AFB would be within cross-range capability. Northrup Strip is not within cross-range capability.

Senator SCHMITT. You have two S-Bands at Edwards. Don't you have backup capability from Goldstone?

General ABRAHAMSON. Yes.

Senator SCHMITT. Why was the decision made to use that Northrup S-Band rather than—I guess you might call it the field S-Band at Edwards?

General ABRAHAMSON. I will have to provide that answer, too. I am sorry; but, I am not in a position to answer that.

[The following information was subsequently received for the record:]

The Buckhorn Space Tracking and Data Network (STDN) station at Edwards AFB is a single link station implemented solely for Shuttle support. This station provides command and telemetry for the STS landing phase and is required to support post-landing testing and operations. The Goldstone station provides metric, command, and telemetry data above 20,000 feet for the Shuttle and support for a number of earth orbiting spacecraft. Therefore, neither of these stations could be deactivated to provide equipment to meet the Dakar requirement.

General ABRAHAMSON. In terms of the operational phase, we do have a series of initiatives [fig. 8] that NASA has had underway for a long period of time, some more recent. But, I think it is worthwhile pointing out that there is very serious planning and very serious work that is going on to insure that we have an effective operational phase.

Organizationally, we have established at JSC Shuttle Effectiveness Office the responsibility to bring together all of the initiatives that would reduce the cost or reduce turnaround time for our oper-

ational phase. Their job is to review and to recommend enhancement initiatives to try to get them in the budget. I will have to say that not many of them have made the budget so far, but we will be trying to allocate a higher level of those to insure that we do in fact meet that need.

At KSC, we have a shuttle turnaround assessment group called a STAG with the same basic objective: to look at enhancements for more efficient and safer operations at the Cape and to improve our vehicle and our cargo process on our payload work itself. In addition, NASA and the Air Force, using a contractor team to support them, have created a committee-type organization, a shuttle turnaround enhancement program called STEP. We are expending contractor resources to back up some of these initiatives themselves. So organizationally, we are tackling that phase of the program.

Procedurally, we have to make a major effort to simplify and improve our procedures themselves so that we can indeed have a reliable, repeatable airline type of operation as we proceed with the program.

Senator SCHMITT. What is the first EVA operation of the space shuttle?

General ABRAHAMSON. I would like to refer that to Dr. Weiss.

Senator SCHMITT. What is the first extravehicular activity?

Dr. WEISS. I don't know if we have a specific schedule; however, the SMM retrieval would be the first possibility. The first one that we have active planning for is a refurbishment activity for the space telescope, which will not be out until 1987. The SMM retrieval is the first that we have, and that is scheduled in 1983.

Senator SCHMITT. There has always been a reluctance in NASA for EVA activity, much more reluctance than the crews have.

Dr. MARK. Things have not changed.

Senator SCHMITT. The management is reluctant. Is a part the consequence of the fact that the space shuttle is designed to make EVA as difficult as you can possibly make it? Is there any of these assessment activities aimed at simplifying EVA so that you can make use of the man in space?

General ABRAHAMSON. At this point I am not aware of any, but given your experience, I will go back and look.

Senator SCHMITT. That experience and the experience of other astronauts that have gone EVA has not influenced management one iota, and I doubt if it will change. But clearly, one of the major advantages of our program, the U.S. program, is that we have successfully utilized man in his own little spacecraft doing useful, important, efficient things in space. Why reluctance still remains to enhance the capability of the spacecraft to support such activity, I don't know.

I think I understand why people who have not had that experience would feel reluctant to commit men to it. Nevertheless, it is a capability that we're going to have to be willing to use more, and unfortunately, the space shuttle does not easily support such activity.

Dr. MARK. Mr. Chairman, if I may comment on that. There is a plan to visit and fix the solar maximum spacecraft: I think we will probably do an EVA by 1983 on that program.

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Dr. WEISS. Senator, in terms of planning, we do indeed have a manned maneuvering unit that has been developed and is being tested to support just that sort of an EVA activity. The planning for the solar maximum mission will include detailed procedures and training for the manned maneuvering unit to accommodate it.

Senator SCHMITT. I understand that. But what I am saying is that the current design of the space shuttle—I believe I am correct in saying, actually takes longer to prepare and execute an EVA than it did in Apollo. It seems to me that is a giant step backward.

Dr. MARK. The problem you have, Senator, is that the shuttle was designed to have a completely shirtsleeves environment. Therefore, the question of how you prepare people to go from the shuttle to the suits and back again is something that causes this time problem to which you are referring. The tradeoff was made between the shirtsleeves environment and the suit environment and the environment we had in Apollo and the suit environment, which was more compatible. That's why you had an easier time there.

Senator SCHMITT. And I never agreed with the tradeoff, by the way. I think you made the shuttle considerably more complex. You made operations considerably more complex with the idea of going to what is a 16 psi atmosphere, mixed gas, and—than what we should have had. I have never understood that decision, except I think it was rooted in the fact that somehow or other all of the black boxes were going to be off-the-shelf black boxes, and so you put them off of one shelf down here and put them in the same environment in space, where you know as well as I do that this was a pipedream and every one of these black boxes was—is not an off-the-shelf item, did not come out of anybody's closet to fly in the space shuttle.

Unfortunately, we are stuck with the legacy of a 16 psi vehicle. And what I am asking you is is there any reconsideration of that as you go into the design freeze phase of this shuttle? One of the principal reasons for it is to simplify the use of man in space outside the spacecraft.

Dr. MARK. There is consideration of a high pressure suit which gets at the same problem in a different way. There is serious consideration of how to reduce the preparation time necessary for EVA.

Senator SCHMITT. Please continue, General.

General ABRAHAMSON. There are a series of technical initiatives [fig. 9]; some of which are on contract right now. I think that the thrust of every one of these things is clear—that is to produce more automated types of activites such as the automated hydrogen tank proof testing, and the computer-controlled weld machining for the external tank. Those listed are some that are currently in production as well as some we feel confident that we will be able to implement.

They are being evaluated now, such as the automatic spraying of some of the temperature systems themselves, the aft dome SOFI, and putting the nose cone on. All of those things are examples of technical initiatives that are ongoing or what we feel confident we will be able to introduce into the process to reduce costs. This is

very vital. I think it is important for everyone to understand that this is not being ignored at this point.

So where do we go, and where do I intend to take the management as we look at getting ready for the operational phase itself? I believe we can make a great deal of progress [fig. 10] in improving further our training and our procedures and we will be making that a matter of major management emphasis itself. I also believe that quality is an important element as we go through it. Parts control is an area that we have seen great gains, as we look ahead to the logistics activity itself. So, I will be trying to automate some of those things. In the Air Force, we have used cost incentives and contracting. I know NASA has as well and I will be trying to find the best possible incentives for all of our contractors. So, we will be moving in the direction of cost incentives to make those very important motivators for the people.

In the F-16 program I introduced a major modernization effort for Air Force plan 4. I believe there is room for that kind of activity at some portion of the program, particularly the external tank and the SRB. So, we will be looking at ways in which we can modernize those plants and produce them more inexpensively which has got to be a cooperative endeavor between the contractors and the Government. We did that in the F-16 program with a 10 to 1 payback ratio.

I will be looking at a constant work force type of manufacturing schedule, as opposed to some of the ups and downs that the program has had, and that ties in, then, with what is an optimum block buy or multiple year contracting kind of situation. But, a key is that many of those initiatives require money up front. We will have to look at the tradeoffs to decide where these things are affordable. Finally, we will have a management focus on payload integration, on launch and recovery operations, and on on-orbit operations to make them efficient and very reliable. This is the direction I intend to take the program.

Now, looking ahead to what Dr. Mark described as an airline type of operational phase, we will not get there immediately. We will transition in a phased way from R. & D. into production. We have to keep those goals in mind.

Senator SCHMITT. You have payload integration. It is my understanding there is not currently a plan to have integrated simulations between the total payload team and the total launch and operations team; is that true? And if so, why do you believe that the experience of past years, the value of such integrated simulations can be ignored?

General ABRAHAMSON. I think there is a great deal of value in the integrated simulations. I do not know that all of the plans prevent that entirely. I do know that because of economic reasons that we have not invested in all of the simulation capability that one would like. We are going back to see where those investments will have the highest payoff. I am sure at least getting as close as possible to integrated simulation for a significant period of time will offer us an advantage. That is not a commitment that we are going to make, that investment is over and above some of the other things at this point in time. But we will look at it.

Senator SCHMITT. Have you had a management evaluation of the gains and losses of integrated SIMS during the skylab program, which would be the closest example of payload operations integration?

General ABRAHAMSON. I have not. I can look at that example.

Senator SCHMITT. I think it would be well worth doing.

General ABRAHAMSON. Now, I would like to move to the block buy [fig. 11], which I know is one of your major areas of interest. The key to a block buy is the contractor's willingness, as well as the Government's, and the Government's ability to fund it.

When I instituted the F-16 multiyear contract, which is the biggest multiyear contract in existence that I know about and the only recent one from the Department of Defense that has in fact reached the Congress on an approved basis of this magnitude, it was a $3 billion block buy over 4 years on the F-16. It took a significant amount of time, with the contractor for him to accept that risk. We provided, through a series of negotiations, ways in which we distributed the risk fairly between the Government and the contractor. So, the first step in a block buy is the contractor's willingness as well as the Government's.

The second step is to see where it is really going to pay off. Many of these things pay off in the subcontractor area. In some cases, they pay off at the prime level where you have an assembly line that you can build at a constant work force level. You have to get down to the subcontractor level to do the very detailed tradeoff studies to find out where you want to put your money. For example, in the F-16's landing gear, when the rate was planned to be 120 a year, part of our problem was that for only 120 forgings, the company had to set up their operation to do those 120 forgings in just a few weeks, check them properly, and then they shut down. The skilled people that were inspecting those particular forgings, then go away on other jobs if other jobs are not there. Therefore they won't be available next year when the company wants to set up again. You lose money and set up time, as well as time when you take it down. All of those are inefficient.

So that is one of the primary advantages of a bloc buy; it is at the subcontractor level. In some cases, it is an advantage if the subcontractors are, indeed, willing and when they can see a larger commitment on the part of the Government. Then, they are willing to invest additional money on their own to automate.

We are not talking about such large numbers that it is going to be a clear advantage in every case. There may be some advantages; but, and the only way you can determine that is to get down to the subcontractor level to study it carefully and to get commitments from those people. This means parallel proposals, both at the subcontractor level and the prime level, that allows you to compare what it would cost if you were going out on a yearly basis against a firm, contractual commitment. What the advantage of a bloc buy is. And, that has to be, first of all, structured, based on studies so that you have, so that you do not waste everybody's time with a dozen different types of proposals. Then one has to come up with a kind of a deal that both parties are willing to accept. So we will be looking at that. And then finally, where it does require a budget decision, increased investment up front to determine how much of

this we can afford. That is the sequence which you have to go through when you institute a bloc buy.

How would you apply it in this program? Right now we have an existing cost plus contract through Orbiter 104. I classified it in this chart as a normal procurement which could be compared to a bloc buy of 104 and a buy of spares. That will be important for operations itself. That is kind of the minimum type of bloc buy. You could also introduce a two-orbiter bloc to try to combine efficiencies in 104 and 105 and buy that as a bloc. On the part of a contractor, that is a 3- to 4-year commitment. In my judgment, as based on discussions with a series of Air Force contractors, that a 4-year commitment is the kind of contract commitment that you would like. This is about the maximum that you could accept the first time.

Later on, if the demand justified a larger number of orbiters, you might look at a subsequent bloc of some kind. The bloc buy that makes the most sense to me now is looking at Orbiters 104 and 105 in a combined way. Dr. Mark indicated what the decision timing is for that, since we are already on contract for Orbiter 104 and he indicated that we can do that at the time of the 1984 budget. It is late. We would like to do that earlier, but it is still possible at that point in time. So, the way we would look at it now is that over the next period of time we will start out with studies looking at precisely that. I will be taking this proposal to Rockwell management on Friday to investigate the first step and to see what their interest is, because they have to be seriously interested or it is not going to pay off.

We will be looking at these series of options to determine what the advantages are, and what the costs are. The results will be presented to Dr. Mark and Mr. Beggs and to the administration. Eventually, there will be issues that will have to come to the Congress itself. In the bloc buy and multiyear contracting which the Department of Defense has embarked on, there have been major policy issues that have required a great deal of discussion, and in fact caused consternation both in the Congress and the Department of Defense.

Senator SCHMITT. Is a fourth option, a five-orbiter bloc, a logical extension of the two-orbiter bloc?

General ABRAHAMSON. It might be, but the key would be when you know enough about the demand to make that decision.

Senator SCHMITT. The only reason that we don't know enough about demand is that the Air Force is not committed yet. Right? And anybody who is watching what the real world is—it's going to be in space in terms of civil and defense activities. You come down to the conclusion that to carry both loads you are going to a need significantly larger number of orbiters, particularly to take care of any problems that may exist. That may come up with one orbiter, or two.

I am suggesting that at least you ought to be carrying over here on another parallel disk the analysis of a larger buy, because this next year is going to be critical to making those kinds of decisions. At least the Air Force is now, and the DOD has embarked on having an office. It is trying to think about these in an integrated way. We ought to at least be preparing our procurement thinking

so that we may move off to do what I think is clearly going to be warranted by demand.

I think most everybody from the outside, at least, looking in, agrees with it. The demand is going to be there. It is there now. It is just that the Department of Defense and to some degree other parts of the administration have not recognized it.

General. Abrahamson. I believe that we can predict the Air Force demand better than we can predict the civil demand, and that we know precisely what those budgets are for satellites. It will depend to a significant extent on the budgeting for the overall program. The part that may be more difficult to deal with is the civil side, where the people will, indeed, look for the best deal. They may, in fact, opt to Ariane.

Senator SCHMITT. They will opt to the Ariane because they do not see the United States making a commitment. And commitment is what is necessary to continue to keep that civil demand open ended.

I tell you, as long as we drag our seat, that is exactly what they're going to do. They deal in dollars and cents, and not in programs that are dependent on what happens over here in the Congress.

General ABRAHAMSON. There are two variables—the contractor's willingness to take on a large volume over a very long period of time and the Government's willingness to face up to what those initial costs might be.

Let me just give you one example from the F-16 program. These are real numbers [fig. 12] that have been presented to the congressional committees. As you can see, what these show are savings on an approximately $3 billion program of some 480 aircraft. We looked for savings in all of the components of the program, not just the airplanes themselves. We looked at it in the GFE areas, support equipment, and spares. Our initial study for a 4-year block buy of 480 aircraft of 10 per month was $470 million. When we finally got the contractors to agree to a plan that met the budget and what they agreed to do, it looked like about $350 million for that first block. That is a savings of about 10 percent. I think the well-structured block buy programs can give you a greater savings than 10 percent.

We already extracted in the F-16 a great deal of the modernization savings. I would predict that depending on the character of the block buy that we can get somewhere between 10- to 15-percent efficiency, maybe more.

Senator SCHMITT. In a block buy that involves a small number of vehicles, don't you have to—doesn't rate of purchase become more significant as a variable than it would where you are dealing with a large number of vehicles?

General ABRAHAMSON. Interestingly enough, if you reduce it to a per vehicle basis, there is greater savings when a small number is spread out than when there is a mass-produced line like the F-16, where you are producing so many.

Senator SCHMITT. A small number spread out?

General ABRAHAMSON. Yes, sir; the savings potential per vehicle is greater.

Senator SCHMITT. Is that due to the nature of the assembly process, the so-called assembly line?

General ABRAHAMSON. Yes; the business of starting and buying something and then stopping is a terribly inefficient process.

Senator SCHMITT. That is inefficient whether you have small numbers or large numbers.

General ABRAHAMSON. Yes; however, when you have large numbers, you can at least dedicate a larger number. You don't stop and start as often, and the time frames between those stops and starts are not so long.

Senator SCHMITT. So going to 10 months versus 15-month centers with a small buy does not gain you as much as stretching it out actually would?

General ABRAHAMSON. The rule I have always used as a manager is that there is only one way to save money, and that is to do it simpler or faster. Of the two, doing it faster is usually the most efficient.

Senator SCHMITT. Maybe I misunderstood you. That's why I thought it might be important.

General ABRAHAMSON. I was not comparing two different positions in the way we would produce orbiters, but to an orbiter kind of block buy versus an F-16 or a mass production type of block buy. I am sorry if I miscommunicated.

Now, one of the key policy questions is that it costs more ahead of time, and this has been dealt with. You develop a cancellation ceiling [fig. 13] because of what happens when you get a commitment all the way through to the subcontractors. This has been a major policy issue that I had to deal with at the DOD level, the OMB level, and the congressional level. It is the kind of policy question that asks whether the Congress is willing to take on a multiyear commitment from one Congress to another. In the Department of Defense, we have used full funding as a policy. A very important question is: "What is the nature of covering that commitment with appropriated funds, or would you accept a contingency liability?" The cancellation ceiling question that develops in every one of these proposals, Is it a contingency liability?

So, the policy issue, then, is do we appropriate for that or not. Money is paid if somebody cancels the program. So that is a policy issue. You can see at least on this program it was a major policy issue. When it got up to $280 million in one fiscal year, the Department of Defense decision was to go into the full funding policy on the F-16. That may not apply to all.

Using the F-16 example, with savings spread out [fig. 14], you can see at least over that block buy the kinds of savings. The largest savings are always in the outyears, not in the early years, so that the net of the cancellation ceiling and the outyear savings is that it costs more in the early years, and that is a very difficult question. The tradeoffs have to be looked at.

I can assure you that I am vitally interested in this area, and we will proceed in evaluating this. Both the administration and the Congress will have an opportunity to review the results.

Senator SCHMITT. I hope you move expeditiously. This committee has been asking that question for some time. You owe us an answer. You are behind on that answer. I don't blame you, since

you just came on board. But we really have to prepare ourselves and the Congress for the kind of decisions that a block buy is going to mean.

Now, on the defense side of things, we made some significant progress. We have in both authorization bills significant encouragement of multiyear procurement. On other methods of increasing the efficiency of procurement, the Appropriations Committee has indicated its willingness to go along with those initiatives on the defense side. I see no reason why we cannot do the same with NASA, but we have got to have some information from you guys. You just have not been forthcoming on this issue.

General ABRAHAMSON. The issue is a difficult area that requires detailed study. I believe that we can by February have some additional information about progress and how we are proceeding with the study. I believe if the contractors are willing, we can begin to have some very definitive data that would be based on proposals or very detailed estimates, in the late summer.

I would like to summarize [fig. 15] and say that I think STS-1 and STS-2 are a success. Based on that, we ought to plan on a very, very fruitful operational stage for this program. They all point to effective operations. We now have a very aggressive effort looking to the operational phase. We are going to look at other kinds of initiatives to try to make that really meet all of the potential that it can. For the block buy, the decision process will be in the fiscal year 1984 budget.

Senator SCHMITT. Dr. Mark, you are going to have to leave in about 15 minutes? Could I ask you a few questions before you do? And you may want to defer.

Dr. MARK. I may not have to leave, Mr. Chairman. I just asked Mr. Murphy to find out whether the scheduled meeting is still on, but I would be happy to answer questions.

Senator SCHMITT. What I want you to have a chance to comment on is your view and NASA's view of the commercialization aspects of the shuttle, and I presume Dr. Weiss is going to talk about that. I would like to have your thoughts.

What do you see as the most critical aspects of attracting greater commercial use of the shuttle?

Dr. MARK. I think there are two important factors. One is pricing policy, of course. The other is flexibility of scheduling. That is, can we guarantee people a given launch date knowing that there are other things in the mission model that may change. Dr. Weiss might want to comment on both of these issues.

Senator SCHMITT. When you say "flexibility of scheduling," you are including in that the certainty of schedule, the fact that the flight is going to be there approximately——

Dr. MARK. That's right. We need to guarantee them a flight date at some point. When one looks at the four-orbiter fleet and the way it operates, people see rigidities in that model. Then they fear that if something goes wrong in a prior flight they will not get their flight. That is essentially the problem. One of the things we are talking about now, for example, is to put some extra external tanks and SRB's in the pipeline to alleviate that kind of a situation. I believe that once we get into a reasonable flight rate, we will learn

how to incorporate such flexibility without too much difficulty. I do not think it is a really difficult problem.

Senator SCHMITT. Do you sense any difficulty in the lack of dedicated commercial orbiters and the fact that the DOD looms on the horizon as a potential threat to usurp flight time?

Dr. MARK. There is a concern on priorities. Again, that is something that is going to have to be worked out. If the DOD priority is exercised twice a year, then we have a problem. If it is exercised once every 5 years, then it is not.

Senator SCHMITT. The alternative is to dedicate a fleet?

Dr. MARK. Yes; I'm not opposed to that, Mr. Chairman.

Senator SCHMITT. So it is more than just efficiency of buying orbiters that points toward a need for block buy and more than just two. It is the question of building a reliable—you call flexible, and I call it certain—launch capability for the commercial sector.

Dr. MARK. I think that's a fair statement.

Senator SCHMITT. So an eight-orbiter fleet for dedicated commercial and for dedicated defense, as a hypothetical model, with obvious support, one way or the other, depending on what happens during operations, would make a great deal of difference in the attractiveness of the Shuttle for the commercial sector?

Dr. MARK. I am sure it would. Let me say I would not oppose an eight-orbiter fleet either.

Senator SCHMITT. Dr. Weiss, do you want to comment on that issue?

Dr. WEISS. I think that issue is actually a very good takeoff point for my comments on our perceptions of demand and the things that are driving that demand.

Senator SCHMITT. Why don't we save that for a moment, just in case Dr. Mark must leave us.

Dr. Mark, what role do you see for the early basic research programs involving spacelab and other activities in attracting commercial customers? For example, materials processing?

Dr. MARK. We have one flight that we will be conducting fairly soon in which to make a test of the electrophoresis experiment which is a joint venture between two corporations will be conducted. We expect that that is going to be a very interesting experiment and one with great promise. I think there are, scattered through the technological landscape many cases where small amounts of very specialized material have enormous economic leverage. If we can prove that producing these materials in zero gravity conditions is the right thing to do, then we have a very real commercial possibility here—one that we ought to push. I think it is very promising myself.

Senator SCHMITT. You have one consortium, do you not, involving Johnson & Johnson and McDonnell Douglas?

Dr. MARK. Yes.

Senator SCHMITT. On pharmaceutical production using electrophoresis processes. Do you look at that as a very important test case for your being able to provide a reliable schedule so that their return on investment is not seriously compromised in that activity?

Dr. MARK. Actually, Mr. Chairman, I think the shuttle will be used more as an experimental test bed to see how it works. Let me talk a little bit about what we anticipate. The real way we expect

to run these factories is to put them on permanent facilities in space. Both Mr. Beggs and I have talked about that. Now I would expect that the electrophoresis experiment would be done on such a facility. We would go visit it occasionally to withdraw the products that are made and fill in the feedstock, so to speak, and let it run for awhile again.

I would expect that in the biological area, especially, to see factories of that kind hooked onto these permanent facilities that we have been talking about. I believe that is the kind of thing we are going to see easily in the next decade.

Senator SCHMITT. When you look at it more philosophically, we have seen an explosion of the use of space for communication activities, even communications is somewhat more bounded in its potential than that area we have generally referred to as materials processing.

Is it realistic to think that there are any limits right now, definable limits, on what materials, useful materials, may be processed in space for a variety of activities?

Dr. MARK. Mr. Chairman, I believe that in the biological area, there are few limits. I really think it is an area where we are undergoing today a genuine scientific and technical revolution—the understanding of the genetic code; the understanding of how you artifically synthesize molecules that heretofore were only biologically synthesized; and the understanding of the mechanisms that make the nervous system work and ultimately, of course make the brain work.

All of these things are now going on in our laboratories. The characteristic aspect of all of these, Mr. Chairman, is that we are dealing with a chemistry that operates at energy levels which are very much smaller than the normal chemistry. They, therefore, are very exquisitely tuned techniques that have to be used to separate out the various important molecules. Electrophoresis is one of these techniques. If you remove gravity, you make it so that you can tune it ever more finely which is, of course, the whole idea. I think the possibilities are limitless.

It is exceeedingly important to understand, Mr. Chairman, that the United States is well ahead of all other nations in this area. Through our lead in the area of biological chemistry and molecular biology, we will be able to create and then dominate certain markets that do not even exist today. I see an analogy between what is happening today in our biological laboratories and what happened in the electronics business 15 or 20 years ago, when transistors became first commercially available. We developed a lead. We took advantage of that lead for a decade and a half.

Senator SCHMITT. I hope the analogy is not complete.

Dr. MARK. No, sir; there's nothing wrong with that analogy. What is important to recognize is that we should stay ahead. Good people are going to come in and copy what you do. You cannot prevent that. What you can prevent is to have other people snatch the lead on you by stopping to make investments in new things. That's what we have to do.

Senator SCHMITT. I think you would agree, Dr. Mark, the reason we are ahead is that we have publicly and privately sponsored research in biotechnologies in bioscience. And if we cease to fund the

basic research, whether it is in space or elsewhere, and whether it is basic science, or basic engineering, or combination of the two, we will not see that analogy come to fruition again. That is, the point I am getting at is that the early flights, the shuttle and the spacelab and other aspects of it, do provide the basis for decisionmaking by a much broader spectrum of commercial users than has even entered the field today and has indicated interest in buying payload space on the shuttle.

The materials processing, including the biological area, is probably the most openended of the field. The communications satellites we know are going to be expanded. There are going to be refinements. Some of them may be brought on by political decisions throughout the world. Some of them by technological decisions. But it is extremely important to see that these kinds of research applications of the space shuttle continue to be used, so we can bring back melted material in sufficient quantity, so that the industry that uses high purity metals of various kinds can see how much a difference it makes to have 10 percent or 100 percent more pure material than they have had, than they can afford to make here on earth. So far, we have not been able to give them the 500 pound or 100 pound batch of material to experiment with. We have got to do that.

The French are probably the most obvious competitor right now to the space shuttle, although I suspect there are going to be others trying to buy into those markets. They are actively marketing the Ariane services and have established a Government-private industry group as the marketer of this. I believe it is called Arianespace; is that correct?

Dr. MARK. That's correct.

Senator SCHMITT. How do you react to and view this marketing activity by the French?

Dr. MARK. Mr. Chairman, I welcome competition.

Senator SCHMITT. Do you welcome competition that looks at your pricelists and then undercuts you each time and adds to the subsidy, the tax the French taxpayer must pay?

Dr. MARK. I think that is something in due course they will not be able to do any more, because they also have to live by the ultimate laws of economics.

Senator SCHMITT. In the short term, they may completely decimate our satellite production capacity.

Dr. MARK. I have talked to both the French and some of the European people that are connected with Ariane. The existence of Ariane makes it certain that those of us who are responsible for understanding and controlling the cost of our launch systems will do our job right. You have got to remember, sir, that Ariane is based on technology that is now 20 years old—hyperbolic. It is a Titan-type vehicle. There are clear disadvantages that are inherent in that type of a vehicle. There is no doubt in my mind, how any competition between ourselves and the French will eventually come out.

Senator SCHMITT. Your optimism is encouraging. Some of the people that have been talking to me are not so encouraged when they see us having to compete with a $40 million differential for an Australian satellite system.

Dr. MARK. They have to get themselves established. If I were sitting in their place, I would be doing exactly the same thing. I would be buying in. Once I had the market, I would jack up my prices. That's when the competition gets real. I doubt whether the French taxpayer can stand for subsidizing launch services in the long run, just as our taxpayers would not stand for it.

Senator SCHMITT. So you would expect, with your crystal ball in front of you and maybe some rose color in it or your contact lenses, that the shuttle would have the lion's share of the market once this competitive regime stabilizes in the late 1980's and the 1990's; is that correct?

Dr. MARK. I think so. I would go one step further. I foresee a situation developing where the shuttle—let me reword my statement a little bit. We are to some extent launch-vehicle limited with the shuttle. That is, we have more people waiting in line than we can accommodate. I think what may very well happen is that you would see a situation where judgments will begin to be made about payloads that are uniquely well suited for this shuttle, which would go on that. Then other payloads, where really the shuttle is nothing but a truck, something like Ariane would be used.

Senator SCHMITT. Or a U.S. competitor to Ariane?

Dr. MARK. Or U.S. vehicles. I have said many times that the propulsion technology that we created with the shuttle will lead to a generation of new launch vehicles that will be recoverable but unmanned. For instance, take a solid-rocket booster, put a good cryogenic upper stage on top of that, and you have got a good launch vehicle—one that you can recover the first stage and use it over again. This is something that the French will not be able to do until they decide to develop something new. So, I think we have it in the boundary of the shuttle technology to create a generation of launch vehicles that would even compete with Ariane on its own terms.

Senator SCHMITT. I have never asked you this, and you do not need to answer, if it is difficult, but can you give us a very general view of how the SRB technology compares to that of the MX booster system?

Dr. MARK. Yes.

Senator SCHMITT. The MX was conceived in 1960, around there, but obviously it has been upgraded since in terms of basic solid-rocket technology. Is the SRB a significant step ahead of that?

Mr. MARK. The two things are different. One puts the emphasis on very high reliability, in terms of shelf life; and the other puts the emphasis on size. It is really not possible to compare the two. I think the SRB is by far the biggest solid rocket that we have ever flown. It is 2.5 million pounds of thrust.

Senator SCHMITT. I hope that it has not—it is also the most reliable solid-rocket booster.

Dr. MARK. It is a very reliable system, and I think it is just natural to ask the question: "What do we do, in terms of unmanned but recoverable launch vehicles with SRB's?" We have several ongoing studies dealing with that. I would be happy to prepare a briefing for you.

Senator SCHMITT. We would like to have some background on that, and maybe get into it more deeply in our next set of hearings.

Dr. MARK. I should emphasize we do not have any of this in any program right now. This is simply a technical feasibility study; it is not a programmatic question.

Senator SCHMITT. How is your time?

Dr. MARK. I have another 10 minutes, sir.

Senator SCHMITT. Is there a special review pricing policy underway now, with the two flights under our belt?

Is that being updated?

Dr. MARK. Yes.

Senator SCHMITT. Is there anything to report with respect to the pricing policy as you see it now, versus that that has been advertised over the last couple of years?

Dr. WEISS. I would say only that it is going to be changed fairly shortly. The previous pricing policy, which was derived in 1977, was based on a perception of costs that is quite different from now and also on a perception of the number of flights that would be accomplished over a relatively short period of time. These factors gave us a short-term opportunity to amortize our early operating costs.

What we are doing now is evaluating the variety of options that do two things:

One: Provide us an adequate cost recovery for the taxpayer in terms of our commercial and foreign launches; and

Two: Provide us a means of being competitive.

Also, they lead to options that are somewhat different from those prices that are used to establish the current pricing policy. In addition, we are already in negotiations with the Air Force to modify and, in fact, increase the support which they will be supplying to the operational missions that we will be providing them.

Senator SCHMITT. One of the issues for space launches that obviously is very important, but often not discussed, is insurance. The question of insuring spacecraft, commercial insurance for spacecraft being launched on any particular vehicle—and each vehicle has its own insurance rates, I suspect.

How has the insurance community reacted to the successful flights of the space shuttle?

Dr. WEISS. We have just undertaken discussion with some of the members of insurance community. What I find is not so much a comment on how much they can reduce their rate; but, on how much they can expand their business. As a matter of fact, I was talking to one of the members of a leading insurer who wants to come in to discuss the types of missions that they can see themselves insuring. Leading toward materials processing, for instance, is an area that has not entered into their conceptual thinking to date. They have concentrated on communications satellites. So, that is the most important thing that has come to my vision just now.

Senator SCHMITT. But you would say that the environment for reasonable rates for insuring spacecraft and activities launched or conducted on the space shuttle is certainly no worse than it was before, and it has improved and expanded in terms of the opportunities the community sees with respect to the space shuttle?

Dr. WEISS. That is certainly my perception.

Senator SCHMITT. Dr. Mark?

Dr. MARK. Mr. Chairman, with your permission I will have to excuse myself.

Senator SCHMITT. Yes; and I want to thank you for your cooperation today.

Dr. Weiss, do you have a schedule for providing a revised launch policy, pricing policy, for the commercial community?

Dr. WEISS. We have a tentative schedule. It is frankly being forced earlier than original requirements because we are receiving reservations for 1986, today. Our current pricing policy carries us only through 1985; so, we are going to have to respond to sign launch-service agreements and to assure our customers of their business arrangements. Again, assisted by the competition from Ariane, we will have a revised schedule earlier than had originally been planned.

My expectation is that we will have a new launch policy shortly after the first of the year. In addition; we are preparing options for review by Mr. Beggs and Dr. Mark.

Senator SCHMITT. Does that include the payment schedule?

Dr. WEISS. It will include the payment schedule.

Senator SCHMITT. Dr. Weiss, if you would like to proceed now with your prepared presentation, taking into account the questions that have already been asked, we would appreciate it.

Dr. WEISS. Thank you, Mr. Chairman.

I had a fairly short presentation; but Dr. Mark's discussion allows me to abbreviate it even further.

Among other things, I think his discussion centered on what I consider a key facet of the space transportation operations activity, which is providing assured launch and orbit services to a variety of users. The questions you raised and the application of the capabilities that were discussed by General Abrahamson lead to the question of what our demand is today and how we envision that demand developing over the next 15 to 20 years. What I would like to do is to describe the near-term character of the demand, and then expand to what we anticipate the demand to be and our assurances of getting there as well as enhancing the demand; and, thereby, the expectations of usage of space as a valuable environment.

The first chart [fig. 16] deals with the near-term demand through 1986. That demand is rather well established by reservations including $100,000 earnest money that we received from our commercial and foreign users, as well as the expected launches from the current NASA budget planning. It is not optimistic in terms of new starts. Therefore, I would consider this very realistic, from a NASA standpoint as well as for NOAA, which represents the other civil government portions, and from a commercial and Government standpoint.

We really are showing the demand forecast that could be exceeded, had we additional shuttle capability between now and 1985, in excess of that which we will have. As a matter of fact, we have been required to maintain our expendable launch vehicle fleet through this period, and probably a little bit beyond, to accommodate the very rapid growth, which you acknowledged, in the communications satellite field. By the time we get to 1986, we are running about one-third each usage of flights by NASA, the commer-

cial, foreign, which are at this point totally communications satellites, and the Department of Defense. We have initiated, then, the defense usage at Vandenberg, which provides a very great expansion of that use in 1987.

Now, we do use the forecasting by the Department of Defense in their own documents to supply us with a basis of expectation of need for orbiter usage [fig. 17] well into the latter part of the 1990's; and, that indicates fairly substantial planning for the usage of space by the Air Force. I believe General Abrahamson's observations are consistent with that. With respect to NASA and other civil governments, one can project on the basis of the missions we now have within planning as well as a nominal expectation for continuation of the body of programs that are carried on by NASA, such as space telescope. The support of that system requires some routine reaccess to the system on orbiter, continuation of some land resource coverage, and recovery of systems that NASA will be moving ahead with. It obviously conceives of a continuing interest in space by this administration and succeeding administrations.

Senator SCHMITT. Which curve is the 24-flight rate support?

Dr. WEISS. The 24-flight rate support is related to the set of single lines shown. This is a set of superposed expectations, one that reaches 30 equivalent shuttle flights in 1987 which is the 24 rate. Now, 30 does not equate to 24, but it does, if you look at the currently scheduled expendable launch vehicle capability, as well as the Ariane schedule. What we have shown is a free world launch demand. It does acknowledge those missions that are currently scheduled on Ariane which has some 19 missions booked now.

Senator SCHMITT. So that growth is something over and above what the shuttle plan can support at this time?

Dr. WEISS. Oh, yes; as I said earlier, through 1985 we have to use expendable launch vehicles.

Senator SCHMITT. I'm talking about after 1985.

Dr. WEISS. After 1985, we do anticipate a need beyond the 24 missions per year. The current capabilities, as General Abrahamson noted, take us to 24 per year which gives us an opportunity, as we validate this demand, to inject into our budget requirements—a capability of exceeding that demand, which represent the investment necessary to go beyond 24 by 1984. And, that capability will be both with capacity for the expendable hardware—that is the tanks, the refurbished SRB's and spares—as well as a justification for extending our orbiter buys.

We feel that that gives us a 1984 assessment point. As we noted in the earlier chart, we were up only to 9 shuttle missions by 1984. We also will have about 10 expendable launch vehicle missions by that time. So, we are gradually moving into a period where the shuttle takes over the capacity demand as well as permit us to decrease the usage of our ELV's.

Senator SCHMITT. You are talking about making a decision on shuttle orbiters, how many we should buy. Even with the low buying number, you cannot support the demand you are forecasting for the late 1980's and 1990's?

Dr. WEISS. I believe we have to discriminate between orbiter capability and availability of hardware to support number of flights.

Orbiter capability should provide us about a four-orbiter fleet, acknowledging that it might not have sufficient capacity to handle a major problem at first. But, a four-orbiter fleet should provide us with between 30 and 40 missions per year depending on turnaround estimates.

Even with that four-orbiter fleet, we do not have, however, the tank production and SRB refurbishment activity to support that. In order to provide that capacity, we have to do the things that General Abrahamson described, which is, increase our investment in tooling and facilities.

If we are able to determine that the demand which we have described on this chart is indeed that which we can expect, the capability of doing so through the 1984 budget will meet the concerns that we have here.

Senator SCHMITT. The high, the medium, or the low?

Dr. WEISS. Let's take the medium for a moment. Regarding the impact of Ariane, which is relatively slow in this period, we would certainly have a capability of meeting the medium line by 1988.

Senator SCHMITT. For the four-Orbiter fleet, increased tank and SRB production?

Dr. WEISS. Yes, barring any unforeseen difficulty——

Senator SCHMITT. With one of those orbiters.

Dr. WEISS. Obviously, the basis for the fifth orbiter is to take care of the difficulties, attrition, and downtime. That is the first requirement for Orbiter 105 from a user standpoint.

Senator SCHMITT. This assumes that the DOD demand curve is flat through this period.

Dr. WEISS. This is a fairly short time period for the DOD. There is a fairly sharp rise in their own expectations for usage; but part of that is because of the lead time that is related to the initiation of any major space program. It is in the 5- to 6-year range.

Senator SCHMITT. Somebody better learn how to change that. Go ahead, Doctor.

Dr. WEISS. Earlier, we commented on the impact of communications satellites. Figure 18 shows that impact. It has been the communications satellite growth that has compensated for the slower development of NASA use due to lost money and lost program opportunities as well as the development of defense usage at a slower rate than had been earlier anticipated. This has been an unanticipated growth rate. This growth rate has been the leading sponsor, I would say, of the ESA community and France's determination to provide a competitive system, first with their own needs as a European community and second with a non-United States usage where they can be competitive on special grounds. In addition, this growth rate represents an attempt to capture something like 15 percent of the U.S. market, which is their stated policy.

When translated into equivalent shuttle usage, we use about 100 to 150 transponders per shuttle mission. This indicates how many shuttles per year we can look to fly or have the potential of flying just for communication satellites.

Now, this data really comes from projections by the FCC as well as some external evaluators of commercial usage of space, which include the AIAA and some other special studies by more financially oriented houses. It is both very encouraging and it also reflects

on an aspect of usage which was alluded to earlier. This is the necessity of launching on time. When I said assured launch services are a primary objective, I really meant in large measure "launch on time." The return on investment for a commercial user starts only when he has a transponder on orbit. Therefore, the ability to launch at a particular time is a great measure of how he plans his cash flow and his revenue and business investment.

So the flexible scheduling aspect discussion that was initiated here is certainly very pertinent. In fact, we have been achieving some measure of flexibility. We can anticipate through discussions with the Department of Defense, as well as our internal NASA mission usages, probability of launches for a given mission which gives us an opportunity of booking certain launches at particular times with low probability launches on a demand basis. That demand basis is one of the reasons that Dr. Mark indicated that we are interested in having an inventory of tanks and SRB's that would permit us to operate more on a flight demand basis than on a schedule basis which is dependent upon the serialized availability of tanks and SRB's. I think that will give us a much greater measure of flexibility with only a few of those in inventory.

Senator SCHMITT. How does the Centaur or other upper-stage decision affect this—meeting this demand?

Dr. WEISS. In terms of the near-term communications satellites, it does not affect the demand. The most demanding communication satellite is Intelsat-6. To that end, there are discussions on upgradings of the SUSS class upper stages, the commercial McDonnell-Douglas class, as well as proposed developments of an intermediate class between the Department of Defense and the SUSS class A-booster that are being reviewed by aerospace contractors without evidenced need of NASA participation.

A booster or an upper stage like Centaur, I think, would greatly change some of the expectations of the users in terms of the designs that they could afford to go forward with. But for the near years, I do not perceive that as a great influence. We have the capacity for flying the near years, which I would say would be the next 10-year expectation of commercial communication satellites.

Senator SCHMITT. Doctor, do you or General Abrahamson, do you know the status of the Centaur decision at this point?

General ABRAHAMSON. No, I don't know the answer to it. It is still in a decision stage.

Senator SCHMITT. It is my understanding that the DOD or the Air Force has taken a supportive position for continuing with the modification of the Centaur for space shuttle operations; is that correct?

General ABRAHAMSON. I think it is clear that the DOD, as well as other users, would welcome——

Senator SCHMITT. They have always said that, but it is my understanding that there is a formal position now in support of it.

General ABRAHAMSON. There is a formal letter that has been sent to Mr. Beggs from the Air Force; yes, sir.

Senator SCHMITT. Is that letter available to the committee?

General ABRAHAMSON. I think it could be made available; however because of its contents it should be provided separately.

Senator SCHMITT. Go ahead, Doctor.

Dr. WEISS. Figure 19 is a list of those communication satellite users who are flying on expendable launch vehicles, who will be flying on the shuttle, and who have maintained double booking to assure their launch on the dates that they want them. The list on the right shows the foreign payloads booked, and I can say that some of those foreign users are also booked on Ariane.

Dr. Mark commented on the benefits of having competition; and, I guess, I would have to echo his belief that competition is welcomed. Certainly at this time, it is providing two incentives for us. One of those is an incentive to look very hard at our costs and, therefore, our pricing capabilities. In the long run, we must, indeed, provide a competitive pricing capability and our prices must be related to our cost. So, I think, we are developing in NASA a motivation and an orientation toward cost that might not have been as emphatic if we did not have this competition.

Senator SCHMITT. I am sure there is some logical explanation, but this chart does not seem to be compatible with the chart dated November 30 that has been submitted to the committee, and I believe it is one of the charts that General Abrahamson used in his presentation.

Dr. WEISS. You mean identical to or compatible with?

Senator SCHMITT. I mean in terms of looking at what is the timeframe in which you expect to see those payloads on that chart.

Dr. WEISS. It is variable. For instance, this chart just represents those that have been booked already. The Intelsat's, for instance, go out into 1987.

Senator SCHMITT. I'm just saying that in the chart that we have, the U.S. commercial flights out to 1987 are 10, and the foreign are 8, which does not seem to be compatible.

VOICE. Those may be equivalent flights.

Dr. WEISS. Let me explain what this chart shows. This shows payloads. The chart I showed earlier was shuttle missions. We will average better than three payloads per shuttle mission with the normal delta class communication satellite. For a rough estimate, one might divide by about 3 to get the number of shuttle flights that are required to fly these payloads.

With the Intelsat class payloads which are the Centaur type, it is more like 2 per shuttle. A direct equation cannot be made between the number of payloads that are shown here—communication satellites, and the number of shuttle flights. What was shown earlier was a number of shuttle flights.

Senator SCHMITT. You would say that that estimate of shuttle flights is compatible with this chart?

Dr. WEISS. Very definitely. Again, I would not say that one could take this chart and match it, because this is not a time-phase chart. I would have to take this chart and then cite the particular payloads against the year of their intended launch.

Senator SCHMITT. Am I to assume that that was done in order to come up with the chart that we saw earlier?

Dr. WEISS. Yes; through 1987 it was.

Senator SCHMITT. Yes.

Dr. WEISS. Some of these launches go well beyond that. If you will note, the RCA American Comm., Inc., planned for 10 launches,

carried them, I believe, to the end of the decade as replacement launches.

Senator SCHMITT. Please proceed.

Dr. WEISS. Going from this point and repeating my comment earlier that as my orientation to the user side demands, I have to have assurance that the capabilities are going to exist to which I can commit. So, the availability of hardware that was discussed earlier by General Abrahamson is of vital concern to me. It is the subject of ongoing meetings that he and I have had to discuss the milestones that I have established for need and the milestones that he has to have established for supply.

The other area, of course, is the ability to take this hardware and turn it around effectively. Therefore, the question of turnaround time is a continuing one. Turnaround time, as evidenced by STS–1 and 2, is not the means by which we measure or anticipate downstream capabilities. However, it is certainly providing us with some insight into the areas that we are going to have to concentrate on if we are going to shorten our turnaround times down to the 200- to 300-hour requirements needed to maximize the orbiter usage.

However, the current view at Vandenberg is very, very conservative particularly without the application of some of these groups like the STAG group which was discussed earlier. So, what we did was to say, "Let's presume that the conservatism of the folks at Vandenberg right now were applied. How would that affect our ability to meet our current forecast?"

This chart [fig. 20] attempts to reflect that. The dotted line defines the manifest needs. In other words, what sort of turnaround can we afford with the Orbiter fleet we have available to match the mission model we have been establishing and the schedule that derives from that. You can see that the manifest says that we can get by with those dates for orbiters available for turnaround. The projected capability is the lower of the lines in hatched area. Even applying a maximum contingency from the pessimistic side of evaluation, we are in very good shape to meet the demand with the foreseen turnaround times. If you continue that projection, however, we are not going to meet the expanded usage that we were discussing earlier. So, the necessity of working on turnaround time enhancements is very vital which is why we are bending as much effort to that.

Senator SCHMITT. Did you see things in the STS–1 and STS–2 flights that indicated that you may have been conservative in some areas on turnaround, such as in the tiles?

Dr. WEISS. Actually, our turnaround timing on the tiles is pretty optimistic. I think that STS–2 indicates that we are probably not overly optimistic. In looking to the 200- to 300-hour range, we were seeing no more than a maximum of 200 tiles activity between flights, both in repair and in replacement. STS–2 gave us evidence that that is pretty realistic. We might even beat it.

The area that we have seen in both of these missions is the time necessary in the orbiter processing facility. This is probably the major span of time that we have to work if we are going to very seriously change turnaround times.

We discussed earlier the expansion of demand and how we anticipate it will occur. I perceive some limits to the communication satellite usage simply because there comes a time when even the 20 to 30 gigahertz will have a limited quantity of data that cannot be obtained on orbit without transponder beam interference. On the other hand, we have a vastly expanding miniaturization capability, which will increase the number of transponders that one will be able to carry. Our figure of about 100 to 150 is likely to increase per shuttle flight, so that the number of shuttle flights to support communication satellite will tend to level off, I believe, in the mid-1990's or so. In the expansion of the other areas I certainly concur with the discussion which you covered on materials processing that went beyond the biological considerations that Dr. Mark covered.

What I really see happening is providing the evidence of things like the electrophoresis experiment and the German D–1 mission. And here, I guess, I am not as optimistic in the lead on a personal observation basis as Dr. Mark is, in that I see the Germans concentrating very heavily on materials processing. In fact, they have a Spacelab, which we will be flying in 1985, which is almost totally dedicated to materials processing experiments. Therefore, I believe this is an area where we do have to provide evidence early on to stimulate interest in the U.S. industrial community.

Senator SCHMITT. What about the Soviets?

Dr. WEISS. The Soviets have been doing some work in crystals and in metal depositing. Beyond that, I do not have very good knowledge of it. I suspect there are people in NASA who have a far better knowledge than I have. I really do not know how competitive they are at the moment.

There is another area of usage of the space environment that is starting to surface that I also believe will enhance the utilization of the shuttle; that is the use to demonstrate the effect of gravity on processes that will continue to be earthbound. By determining what gravity causes in the earthbound process, we will be able to enhance the efficiency and productivity of earthbound manufacturing processes by learning how gravity is involved in the equation and treating it more effectively. So, I really look toward a very great broadening of usage. Particularly after we can inject that usage into the industrial community of thinking where people whose imaginations have not been tapped yet and who are not bounded by the experiences that I and my generation have been bounded by.

Senator SCHMITT. I have a few more questions, Doctor, and then we would expect to have some further for the record as well as some final answers to the questions that we submitted previously.

General, you have seen recent dropoff in the rate of external tank production; is that correct? And if so, what has been the problem there?

General ABRAHAMSON. I'm sorry. It is not a dropoff, sir.

Senator SCHMITT. Haven't some problems developed in external tank production so that the rate of production recently has slowed down?

Mr. WEEKS. No. We are at the present time, Senator Schmitt, in very good shape on the first lightweight tank which has to fly with

the STS–6. Tank 3 was ahead of schedule, tank 4 is ahead of schedule, and the one that we have been watching the most, the first lightweight tank, is in good shape.

Senator SCHMITT. Is this a new schedule? Is there any place in the last 2 or 3 years that you have revised a schedule to lower production?

Mr. WEEKS. I guess sometime ago we talked of 40, but then NASA came down with the position that we were in the 32 or 34 class about——

Stan, was that about 6 or 8 months ago?

Dr. WEISS. The numbers Mr. Weeks is referring to are the number of flights that we would accomplish between STS–1 and the close of fiscal year 1985.

About a year ago we had a maximum of 48 flights, which we determined, because of the number of missions required, would be about 40 the beginning of this year. Then by virtue of budget considerations and slippage in some NASA programs, as well as the indicated investment necessary to exceed the 24 rate, the current 24-per-year requirement was laid on which provided us a capability to support the 34 missions scheduled through 1985. But that was fixed last spring, shortly after STS–1.

Senator SCHMITT. Well, wasn't the decision to go to a lower total of launches more recent than that?

Dr. WEISS. No. In May of this year, we had a users conference and at that time provided a mission model which had 34 flights in it. Since then, the slip of Vandenberg by a year has eliminated two of the missions, although there were three involved. We have retained one of those missions, so that the two at Vandenberg have been eliminated from the model which has remained over this past 7 months.

Senator SCHMITT. Do you know what the operational flight rate plan for Ariane is?

Dr. WEISS. I'm not certain. They are planning to have two pads and a crew by 1984. Those two pads have a theoretical capacity of 1 year with a planned usage of about four per year, which would give them an eight-a-year usage.

Ariane, for our Delta class payloads, plans to carry two at one time. Their approach is to launch two Delta class communication satellites at one time. If you translate that into a number of communication satellites, it does give them a fair capacity in about 1984 or 1985.

Senator SCHMITT. Now, regarding their pricing in the foreseeable future—do you expect to see their pricing geared to the announced shuttle pricing?

Dr. WEISS. Their pricing actually today is not equivalent to shuttle pricing. Shuttle pricing is more favorable. However, the financing that has been afforded has been the key reason that those few users who have moved from the Delta vehicle to Ariane have taken that advantage. The financing they afford provides for a very small progress payment prior to launch. The bulk of their payments starts some 6 months after the communications satellite is injected into orbit and, therefore, returning revenues. So, it has been this financing factor that has been, in terms of competition, the difficulty for us. We have, as a result, been discussing with U.S. banks,

particularly, the Export-Import Bank, a means by which financing can be provided that will put the United States in a more competitive posture.

But, the reactions that we have seen from those potential users that are being pursued by Ariane, as well as by ourselves, is that if we can provide shuttle launches, the preference appears to be with shuttle. It is only when we are comparing the disparity of costs between our own Delta vehicle and the price offered by Ariane that we have competitive difficulties.

Senator SCHMITT. You are saying that in spite of the favorable financing, where shuttle is the competitive launch vehicle, you are seeing a favorable competitive position relative to the French?

Dr. WEISS. That is the preponderant position, yes.

Senator SCHMITT. Where might we not have that, such as I understand in the Australian situation?

Dr. WEISS. The Australian situation is not in any way resolved with respect to the launch vehicle. The difficulties in the Australian situation right now lie with the satellite vehicle itself—that is, the communications satellite competition and the financing afforded there as well as the pricing. That, of course, deals with several hundred million dollars, as opposed to the cost of launch, which is something in the 20 percent of the total system. The other consideration that we are concerned with, of course, from a national standpoint is the potential of a joint prospect of supplying the communications satellite as well as the launch that the French are considering.

Senator SCHMITT. Do you have any more details on that for us?

Dr. WEISS. No. I will try and get them for you.

Senator SCHMITT. We would appreciate that.

[The following information was subsequently received for the record:]

The Australian Overseas Telecommunication Commission (OTC) is in the process of selecting the contractor for building the Australian communication satellite to be launched in 1985–1986. Finalists are Hughes, Ford Aerospace, and a combination of Matra-British Aerospace.

Although the American proposals can compete favorably in the technical aspects with the Matra-British Aerospace proposals, the financial conditions offered by Matra-British Aerospace are extremely favorable and mean cost savings in the millions of dollars as compared to what the American contractors can offer.

It appears that the Amercians' technical advantages, which relate to proven performance, are insufficient to overcome the large savings offered by the European combination.

The Export/Import Bank is aware of this situation. They have offered to guarantee the loan, but have not offered to loan the necessary funds to Australia which, of course, would be under terms and conditions more competitve to the European offer.

The Australians requested a video conference call with Mr. Draper, President of the Export/Import Bank, to explain the seriousness and technical competence of the European proposal.

Although this call has been scheduled twice but never made, the situation is still very much alive, and the Export/Import Bank representatives are working with Overseas Telecommunication Commission (OTC) personnel to set up a mutually convenient date to complete the call.

Senator SCHMITT. Now, relative to the cost per flight, in 1977 the cost established was $18 million; is that correct?

Dr. WEISS. Yes, $18 million for a full shuttle.

Senator SCHMITT. For a full shuttle.

Dr. WEISS. In 1975 dollars.

Senator SCHMITT. Right.

Now, as I understand it, 1979, you said that the cost-per-flight estimate had increased by 30 percent in those same dollars; is that correct?

Dr. WEISS. Yes, that sounds correct.

Senator SCHMITT. Now, you are undertaking this launch policy review. Can we expect to see a change in the cost per flight as a result of this launch plan?

Dr. WEISS. Yes.

Senator SCHMITT. Do you expect it to go up or down in 1975 dollars?

Dr. WEISS. Unfortunately, it will go up.

Senator SCHMITT. Because of what? Reduced number of flights?

Dr. WEISS. A combination of reduced number of flights and increased cost of the elements that make up that cost per flight, such as the solid rocket boosters and the external tanks, and an increase in our manpower estimates to support the launch flight operations will effect the cost per flight.

Senator SCHMITT. At least in these areas do you expect that there will be costs that will be in excess of the inflation rate that we normally see in these kinds of activities?

Dr. WEISS. Yes.

Senator SCHMITT. Is the solid rocket booster cost greater than inflation in those areas, and I'm not talking about an average national inflation, I'm talking about inflation in aerospace-type procurements?

Dr. WEISS. If you make judgments based on the 1977 price development, the actual cost of producing the hardware is much larger than the estimate established at that time. I would say that that is not an inflationary growth. It is a growth in the actual cost of manufacture based on design considerations.

Senator SCHMITT. In cost dollars there has been a cost growth.

Dr. WEISS. Absolutely.

Senator SCHMITT. What about in the launch itself? In the launch costs themselves?

Dr. WEISS. In the manpower area, you mean?

Senator SCHMITT. Presumably, if you had increased manpower, you would get a cost increase in constant dollars.

Dr. WEISS. That's correct.

Senator SCHMITT. Would you say that that is the primary increase in the launch cost, is the revised estimate of manpower?

Dr. WEISS. No, I would say the increase in cost is rather well distributed between the hardware and the manpower. They are both substantial and to about the same extent.

Senator SCHMITT. Is the manpower increase a result of just a decrease in productivity or is it unanticipated refurbishment, anticipated complexity, increased considerations for safety?

Dr. WEISS. The last two are the ones that are most correct and, certainly, best defined. That is the increase in complexity, as well as increased safety considerations, is related to complexity. The overall experience in processing the first two orbiter missions has given a harder basis for estimate. That harder basis has been greater than we had anticipated in the initial establishment of the price.

Senator SCHMITT. The combination of experience with the positive results from the various enhancement studies, I believe that is what you call them, wouldn't you expect that to peak out and start to decline again?

Dr. WEISS. We're certainly looking forward to that. We are going to include in our cost and pricing analysis an expectation of substantial reductions in what might be called the unenhanced projections. In fact, we must to be competitive.

Senator SCHMITT. General, I intended to ask you about the so-called enhancement studies. How do you coordinate them? You have got three different groups. What do you do to coordinate those studies?

General ABRAHAMSON. Sir, I know you're very familiar with the level 1, 2 and 3 control that we have at NASA. The primary coordination is done through the level 2 office, which is the integrating office at JSC, and that is the responsibility of Dr. Lunney. I proposed last week to each of the center directors an organizational approach to try to insure that we put more people working on that job, as well as more resources. I think it is quite clear that this is the area that is the challenge ahead of us. The center directors are very receptive to that.

Senator SCHMITT. But you do not see any problem in coordinating those three different efforts? It would not be unnecessary duplication? Some duplication is probably a good idea. You get some new ideas, but do you think that is going to be taken care of by Glynn Lunney?

General ABRAHAMSON. The fundamental organization for the shuttle is one that has relied on the integration activity, and I do not think that should change. I think that has proven itself as an important asset to the program itself. Now, the question is, How do we make that more effective? This question is the one we will be tackling.

Senator SCHMITT. Do you reach out—where these groups are—reach down into the organization? Did people actually working the launches and working the assembly and tests and checkout, get suggestions for how the operation could be enhanced, in particular, with a decrease in time?

General ABRAHAMSON. Yes, sir.

Senator SCHMITT. With respect, on the manpower, Doctor, what is the most labor-intensive aspect of the launch operation? Is it the activities within the orbiter processing facility?

Dr. WEISS. Yes.

Senator SCHMITT. And those consist primarily of what? Just checkout, making sure everything is ready?

Dr. WEISS. It involves the checkout and any refurbishment. It also involves interaction with the payload aspects which forms a fairly healthy portion of the operation. It involves any of the refurbishment of tiles at this time and the processing of the hydraulic system controls instrumentation and the various subsystems.

Senator SCHMITT. Do you have any constraints on simulation facilities for crew training in the launch plan that you are currently looking at?

Dr. WEISS. This is a subject that we spent some time discussing it at Johnson Space Center a couple of weeks ago. The determination

is that we will probably be augmenting some of our simulation facilities; but that on the whole, by careful scheduling, we are going to be able to take care of the near-term requirements.

General ABRAHAMSON. Right now the principal effect is between launch No. 5, where we are using Orbiter 102 and launch No. 6, where we're using Orbiter 099. The Orbiter 099 is a different configuration. It has the heads-up display and some different wiring. Unfortunately, we do not have sufficient simulation capabilities for both flight crews and for overall operations crews to be able to keep both of those different configurations in operation during the overlap period of training. Therefore, the principal effect, in the short term, is what appears to be about a 10-week time difference that we must maintain between launch No. 5 and No. 6. But that is a ripple in the short term. Clearly, it is a problem we have to deal with now, but it is not the long-term issue.

I think what you are driving at for the long term is something that, in fact, does allow us enough full simulation capability that we can have an effective operation with payloads and do that effectively and turn around quickly. I do not know the final answers. As I indicated, we will reevaluate that. Earlier judgments were made in favor of the minimum number of facilities, which was because of the earlier cost problems associated with the shuttle and the extension in time of the shuttle. I think it is now time to reevaluate it.

Senator SCHMITT. Would you expect the simulation time to decrease as you move from the test phase to the operational phase?

General ABRAHAMSON. Yes, sir; in this particular sense. This is one of the lessons that is becoming clear already. We have, in fact, learned in the past that the training time for each astronaut can be reduced if the astronauts' tasks are specialized. We always anticipated specialization. For this last launch, Dick Truly spent a great deal of time training for that particular mission. Some of that training was quite inefficient. He had to go up to Canada to work at the factory as well as travel back to Houston to work. It involved a lot of traveltime.

One of the optimistic results of the flight is that Dick felt the operation of the remote manipulator system [RMS] was an easier task than he had expected so, if we have a specialist who operates the RMS all the time, you can probably cut down those who would be a backup crewmember for the RMS. It is those kinds of issues that will allow us to reduce training. It is important to do so not only for onflight operations but also for the ground operations.

Senator SCHMITT. Did you imply that you would fly crewmembers more frequently in order to cut down on simulation time?

General ABRAHAMSON. I think we would fly as many as we could effectively fly within the payload limitations. A large number of crewmembers will allow you to do that. Our plan is to get more crewmembers flying as early as possible to obtain experience and specialization.

Senator SCHMITT. Do you always expect to have pure—so-called pure pilot professionals in the left and right seats of the Shuttle, or would you at times bring in a pilot-trained engineer or scientist to fill one of those seats, depending on the capabilities you needed in the mission?

General ABRAHAMSON. I'm not in a position to answer that at this point. There is a lot of background and history in that. Obviously, what history is pointing to is, for the immediate future at least, keeping two pilots, because after all the safety of the vehicle has to be the primary consideration.

Senator SCHMITT. Are you suggesting that an engineer and scientist trained as a pilot cannot fly a vehicle safely?

General ABRAHAMSON. I really walked into a trap on that one.

Senator SCHMITT. Yes, you did. Those kinds of questions seem to trap everybody that comes before this committee.

General ABRAHAMSON. For the immediate future, that is the plan.

Senator SCHMITT. I guess some professional bias is allowed to you, General. I still strongly suggest, as I have at other times, that the total efficiency of the mission—of some missions can be increased by having a more broadly experienced and trained person in the right seat of the space shuttle. And there certainly are scientists and engineers who have pilot capabilities, and I think with time, they have shown that they can fly safely in space.

General ABRAHAMSON. Sir, I think that you have demonstrated that clearly.

Senator SCHMITT. I'm not suggesting it myself——

General ABRAHAMSON. Your criteria is the appropriate one; that is, what is the best mix of crewmembers to satisfy the overall mission requirement. I'm not prepared at this point to go beyond and say that we are willing to give up a person with a great deal of pilot experience in the right and left seat.

Senator SCHMITT. I would not expect you to do that.

General ABRAHAMSON. Thank you.

Senator SCHMITT. Gentlemen, I think that probably completes the questions we need to ask today. We will have a few more for the record, and we hope that those other questions that you said you would expand upon for the record will be done so, and done so promptly.

We would like to pursue this area of oversight investigation by the subcommittee early next year.

[The charts follow:]

BLOCK BUYING TIMING

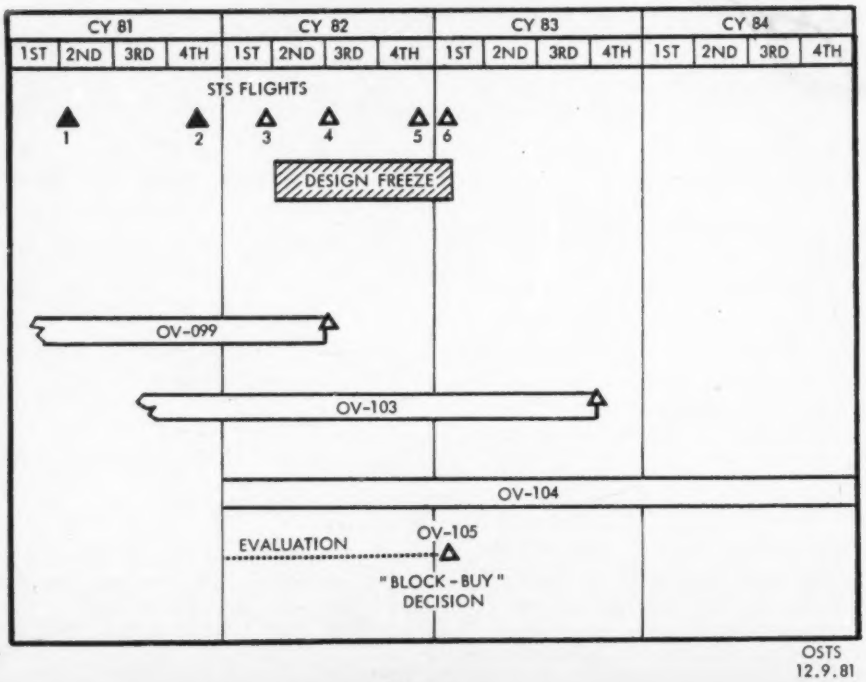

Figure 1

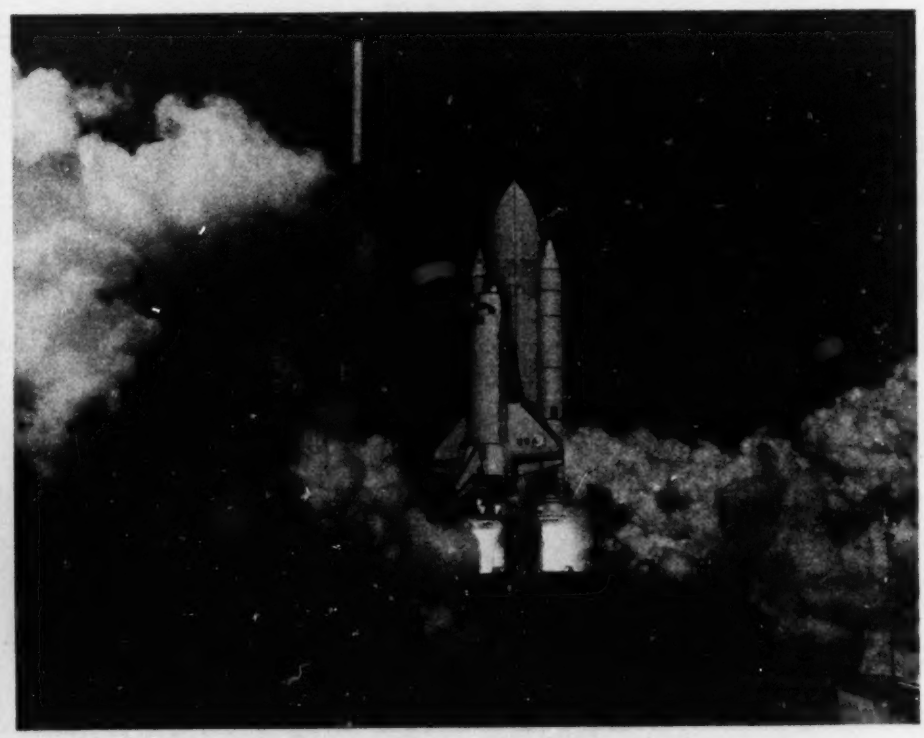

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Figure 3

ASSESSMENT OF STS-1 AND STS-2

Overall vehicle performance on both missions was outstanding: Anomalities well below level expected; astronaut reports—exceptional handling characteristics; and thermal protection system—better than expected.

Major flight objectives accomplished:

STS-1.—All major flight objectives accomplished; and demonstrated viability of STS.

STS-2.—90 percent of planned high priority flight objectives performed; demonstrated reuseability of the orbiter vehicle; and demonstrated capability to support payloads.

Implication for operations—"Positive."

Figure 4

PRODUCTION CAPACITY (CHART 1)

External tank: currently—10 to 12 per year; present plan—24 per year by 1987; can increase production with investment; and flight rate—24 per year by 1988.

Solid rocket booster sets: currently—8 to 10 per year; present plan—24 per year by 1987; can increase production with investment; and flight rate—24 per year by 1988.

Figure 5

PRODUCTION CAPACITY (CHART 2)

SSME (main engines): not facility constrained; present rate—3 per year; rate can increase with additional funding; and flight rate plan—24 per year in 1988.

Orbiters: tooling/jig capacity—one per year; 099 and 103—15 month deliveries; and 104 delivery—budget and workforce decision.

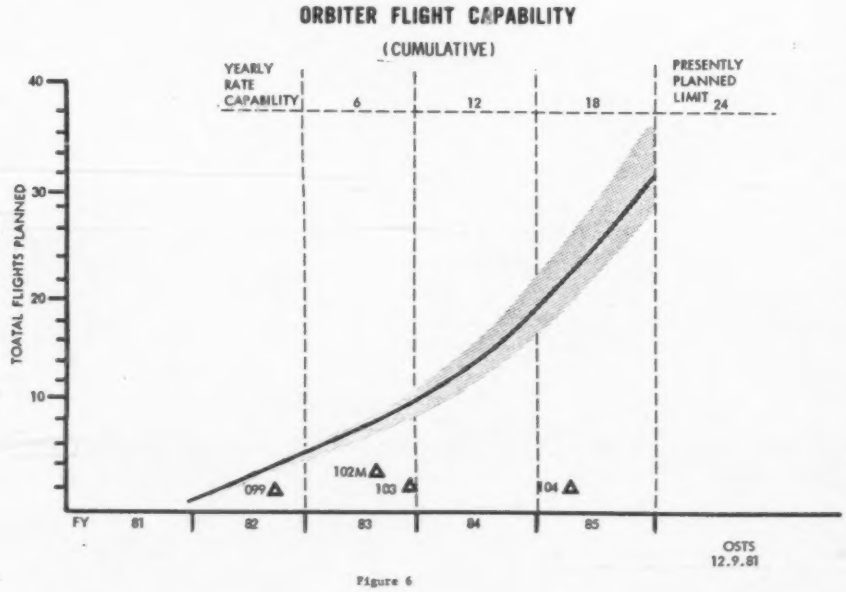

Figure 6

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Figure 7

OPERATIONS SUPPORT

Launch pads: VAFB—October 1985; and Pad B (KSC)—IOC September 1986.

TRACKING GROUND SUPPORT

Landing site	S-band	C-band	UHF	MSBLS	TACAN
KSC	X	X	X	X	X
Edwards AFB	X	X	X	X	X
Northrup Strip	(STS 1,2)	X	X	X	X
Hickam AFB			X		X
Rota NS, Spain			X		X
Kadena AB, Japan			X		X

Figure 8

INITIATIVES FOR OPERATIONS

Organizational: JSC—STS effectiveness office—review, recommend enhancement initiatives/KSC—Shuttle turnaround assessment group (STAG)—enhancements—vehicle and cargo processing; and NASA-USAF—Shuttle turnaround enhancement program (STEP)—NASA and contractor team—improve turnaround at KSC and VAFB.

Procedural: Major effort—simplify and improve realiability.

Figure 9

TECHNICAL INITIATIVES (TO REDUCE COST)

Currently in production: Computer controlled weld/machining (ET); automated LH_2 tank proof testing (ET); automated SOFI operations; reclassify expendables to reusables (SRB); ship pressurized tank (ET); and more. . . .

Planned: Increased injection molding of parts (ET); automated SLA spraying (ET); alternate AFT dome SOFI (ET); install nose cone at Michoud (ET); change AFT skirt cork to TPS (SRB); and more. . . .

Figure 10

FUTURE DIRECTIONS

Improved training and procedures.
Automated quality and parts control records.
More cost incentive contracting.
ET and SRB manufacturing modernization.
"Constant workforce" manufacturing schedules.
Block buy/multiyear contracting (where affordable).
Management focus on: Payload integration, launch and recovery operations, and on-orbit operations.

Figure 11

BLOCK BUY POSSIBILITIES

Initial actions.
Contractor willingness.
Subcontractor tradeoff studies.
Parallel proposals.
Budget decisions.
Potential options.
Normal procurement—OV-104.
Key subcontractor block—OV-104 + spares.
Two orbiter block—OV-104* + OV-105.

*Recontract for OV-104.

F-16 MULTIYEAR CONTRACT STUDY - PROPOSAL COMPARISON ($ MIL)

	F-16 SPO MULTIYEAR STUDY			GENERAL DYNAMICS PROPOSAL* (20 MAR 81)	
	5-4 783 A/C (8/MO)	5 480 A/C (8/MO)	4 480 A/C (10/MO)	5 480 A/C (8/MO)	4 480 A/C (10/MO)
CFE AIR VEHICLE	$ 532	$272	$219	$422	$331
MAJOR GFE COMPONENTS	155	80	67		
SUPPORT EQUIPMENT	22	22	21	25	19
SUBSYSTEM TECH MOD	151	77	83		
AFSC SAVINGS	$ 860	$451	$390	$447	$350
SPARES	144	80	82		
TOTAL SAVINGS	$1004	$531	$472	$447	$350

* INCLUDES MSIP AND SUPPORT EQUIPMENT ESTIMATES

OSTS
12.9.81

Figure 12

Figure 13

F–16 MULTIYEAR CONTRACT CANCELLATION CEILING

[Then-year dollars in millions]

Time period	Fiscal year	Unfunded ceiling
August 1981 to October 1981	1981	$261
November 1981 to October 1982	1981	283
November 1982 to October 1983	1981	180
November 1983 to October 1984	1981	57

Includes airframe, AME, support equipment and AIS.
Maximum value equates to 11 percent of contract price.

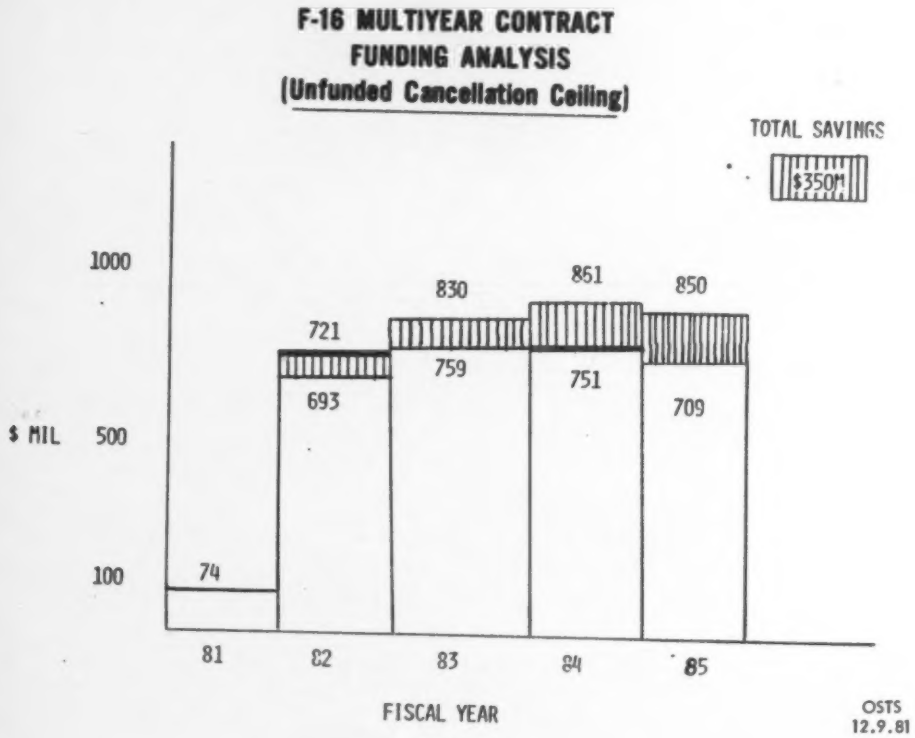

Figure 14

Figure 15

SUMMARY

STS–1 and STS–2 successes: "Point to effective operations."

Present operational planning: Based on 24 flights per year; and, aggressive actions underway.

Future initiatives: To reduce costs and timeliness; evaluate block-buy advantages; and decision—fiscal year 1984 budget.

Figure 16

SPACE SHUTTLE MANIFEST TRAFFIC DISTRIBUTION (32 FLIGHTS THROUGH FISCAL YEAR 1985)

[Fiscal year]

	1982	1983	1984	1985	1986	1987
Kennedy Space Center:						
NASA and other civil government		4	4	5	5	7
U.S. commercial	1		2	3	3	2
Foreign		1	1	1	2	3
Department of Defense (Rev. 10A)			2	4	5	5
KSC total	1	5	9	13	15	17
Vandenberg Air Force Base:						
NASA and other civil government					1	
U.S. commercial						
Foreign						
Department of Defense (Rev. 10A)					1	6
VAFB total					2	6
Manifest total	1	5	9	13	17	23

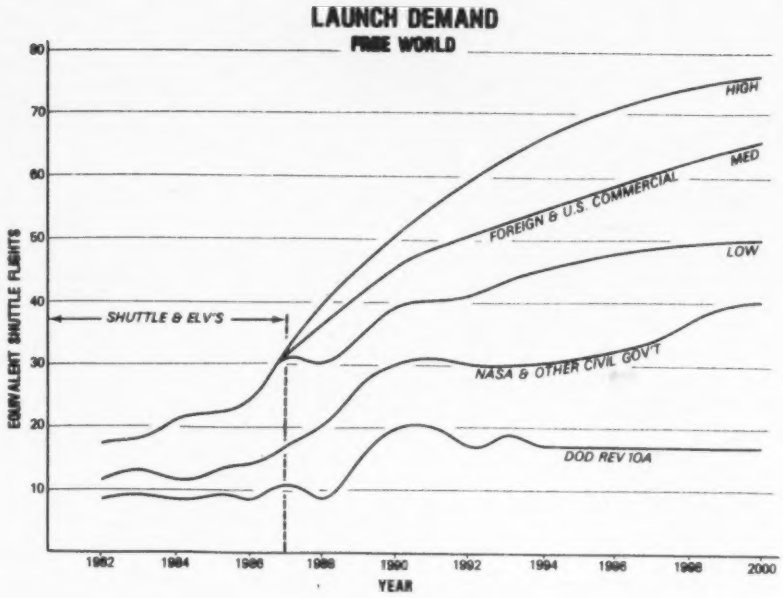

Figure 17

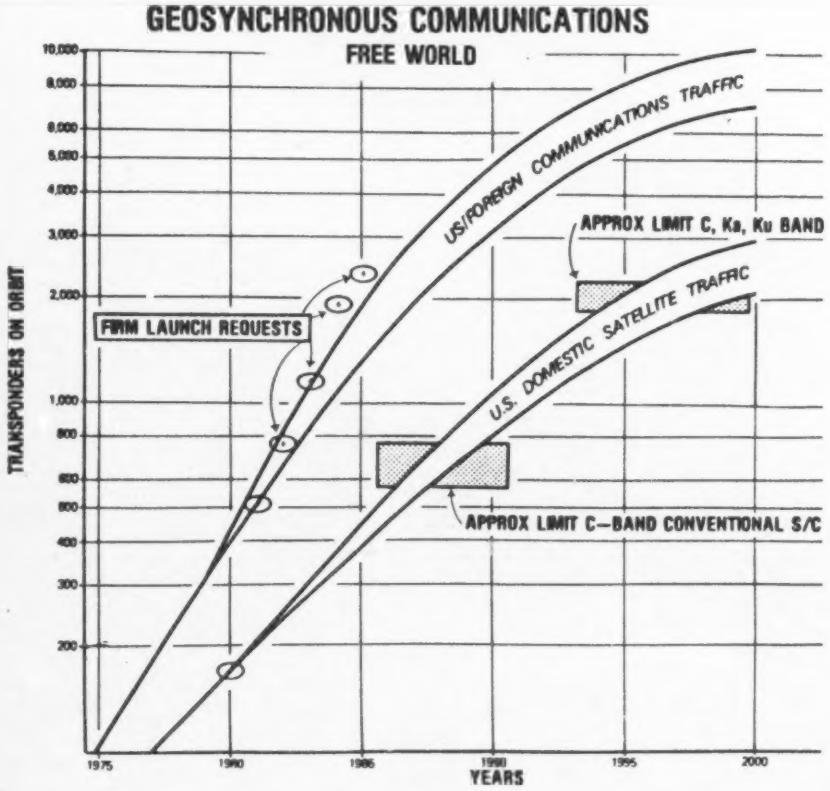

Figure 18

SHUTTLE/ELV REIMBURSABLE USERS
(EXCEPT OTHER U.S. GOVERNMENT AND DOD)

DOMESTIC PAYLOADS BOOKED					FOREIGN PAYLOADS BOOKED				
USER	TOTAL	ELV ONLY	SHUTTLE ONLY	DOUBLE BOOKED	USER	TOTAL	ELV ONLY	SHUTTLE ONLY	DOUBLE BOOKED
AT&T LONG LINES	3	1	1	1	WEST GERMANY (BMFT)	2	–	2	–
GTE SATELLITE CORP	4	2	2	–	MBB (WG)	1	–	1	–
HUGHES COMM, INC	6	6	–	–	TELESAT CANADA	10	1	9	–
HUGHES COMM SERVICES, INC	5	–	5	–	INDIA	2	1	1	–
SOUTHERN PACIFIC COMM	3	–	–	3	INDONESIA	2	–	2	–
SATELLITE BUSINESS SYSTEMS	4	2	2	–	ARAB SATELLITE COMM ORG	2	–	2	–
SPACECOM	4	–	4	–	AUSTRALIA	4	–	–	4
SATELLITE TELEVISION CORP	2	–	2	–	COLOMBIA	2	2	–	–
COMSAT GENERAL CORP	4	4	–	–	ITALY	1	–	1	–
RCA AMERICAN COMM, INC	16	5	10	1	JAPAN (SHARED SPACELAB)	1	–	1	–
WESTERN UNION TELEGRAPH CO,INC	4	2	–	2	UNITED KINGDOM	2	2	–	–
U.S. SATELLITE SYSTEMS	1	1	–	–	NATO	2	2	–	–
AMERICAN SATELLITE CO.	3	3	–	–	RADIO–TELE–LUXEMBOURG	3	–	3	–
					INTELSAT	15	–	12	3
					CNES (SHARED SPACELAB)	1	–	1	–
TOTALS	59	26	26	7	TOTALS	50	8	35	7

OT–81–0080
12/8/81

Figure 19

SHUTTLE TURNAROUND ASSESSMENT
KENNEDY SPACE CENTER
(5 DAYS, 3 SHIFTS)

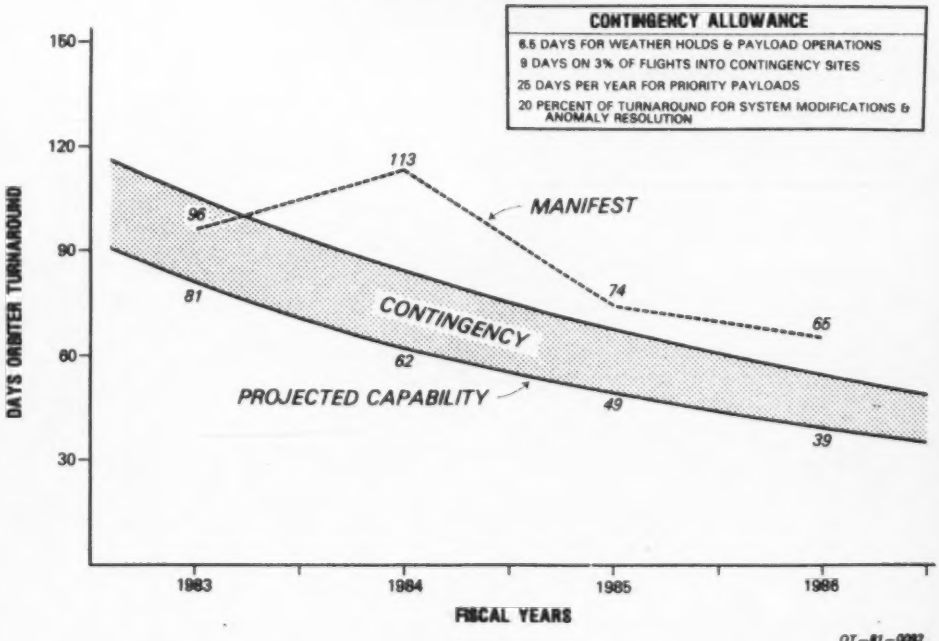

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Figure 20

[The followng information was subsequently received for the record:]

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

SHUTTLE OPERATIONS

Question. Describe the key elements and subelements of the Space Transportation System Operations including what percentage each key element makes up.

Answer. Part I—The key elements of Space Transportation System (STS) Operations and a description of their subelements are as follows:

Element.—Space Shuttle Operations includes that effort required to maintain and operate the Space Transportation System. The various subelements are included below:

Subelement—*Orbiter Hardware Support* includes replenishment and transportation of line replaceable units, shop replaceable units depot maintenance manpower to support orbiter hardware maintenance during operations. Further, this includes the orbiter subsystem unique ground support equipment overhaul and repair, consumables and ancillary equipment. Some specific examples of major hardware are fuel cells, tiles for thermal protection, tape recorders, leading edge support structure, wheels, brakes and pyrotechniques.

Also included is a level of sustaining engineering manpower required to provide support to the Flight Software Laboratory (FSL) and the Shuttle Avionics Integration Laboratory (SAIL) for ongoing operations as well as manpower to support redesign to reduce costs and anomaly testing.

Subelement—*Crew Equipment* includes cost of replacement spares, replenishment hardware, field support and maintenance of crew related equipment. Major items of equipment are the Extra-Vehicle Maneuvering Units (suits), portable oxygen systems, headsets, radiation instrumentation, survival radios, closed circuit TV and cameras.

Subelement—*Main Engine* includes prime contractor activities for major engine overhauls, spare parts and sustaining engineering associated with SSME overhaul, refurbishment and anomaly testing.

Subelement—*Solid Rocket Booster* includes prime contractors' activities to provide solid motor reusable and expendable hardware, booster hardware, both reusable and expendable, and labor to support refurbishment of hardware to support operational flights.

Subelement—*External Tanks* includes prime contractor activities to support manufacturing, assembly and delivery of external tanks for operational flights.

Subelement—*Propellants* include all flight base propellant excluding solids. Also included are power system fuels and oxidizers, pressurants, purging gases and fluids, and the plant cost at the Michoud Assembly Facility (MAF) for producing liquid hydrogen.

Subelement—*Ground Support Equipment Spares* includes replenishment spares for ground support equipment used in launch processing at the Kennedy Space Center (KSC). Some specific examples are Solid Rocket Booster hold down posts, components for the tail service masts, valves for the hydraulic subsystems, liquid oxygen main fill pumps, crawler shoes for the mobile luanch platforms and magnetic tapes used in the launch processing system.

Subelement—*Flight Operations* includes operating, maintaining and modifying onboard avionics software and ground mission control systems; mission planning and documentation; and maintenance of simulators. Flight operations also includes support to crew operations and training, substaining engineering for flight operations, analytical integration and program support.

Subelement—*Launch/Cargo Operations* includes manpower required to conduct vehicle ground operations required to process the orbiter, external tank, the SRB's and main engine. Also identified with launch operations are contractor manpower required to operate and maintain the ground support equipment; conduct SRB retrieval operations; support to modification redesign, configuration identificaiton and inventory control. Logistics, facility and engineering modifications and KSC program support are also included.

Identified with Cargo Operations is contractor manpower required to provide standard processing services for integration of the payloads with the orbiter vehicle.

Element—Spacelab Operations includes flight hardware, consumables, spares, transportation flight operations, launch operations and program management support unique to Spacelab during the operational time frame.

Element—Upper Stage Operations includes the Inertial Upper Stage (IUS) and the Spin Stabilized Upper Stage (SSUS) flight hardware for NASA missions as well as the wide-body Centaur identifed for Galileo, International Solar Polar (ISPM) and the Venus Orbiting Imaging Radar (VOIR) mission. Also included are consumables, spares, transporation, flight operation manpower, launch operations manpower and program management support unique to NASA upper stage operations.

Element—Payload Support Operations includes that effort required to provide Shuttle payload related optional services to NASA and reimbursable users. These services include development of unique integration hardware, spacecraft to upper stage analytical integration, and payload support at the launch site.

Part II—Regarding the percentage each element contributes to the total of Space Transportation Operations, the breakdown for fiscal year 1981, a year in which development activities were predominate, is as follows:

	Percent
Shuttle operations	82
Spacelab operations	0
Upper stage operations	11
Payload support operations	7

A further breakdown of the subelements of Shuttle Operations is as follows:

	Percent
Orbiter hardware support	.5
Crew equipment	.5
Main engine	1.0
Solid rocket booster	28.0
External tank	34.0
Propellants	1.0
GSE spares	0
Flight operations	17.0
Launch/cargo operations	0
Total	82.0

Question. How do the percentages of each element differ from the design, development, test, and evaluation (DDT&E)?

Answer. Fiscal year 1981 and fiscal year 1985 were chosen as representative years in order to compare the STS Operations level of activity during the DDT&E phase of the Space Shuttle to a year in which operations were well underway.

The enclosed chart (Chart A) portrays the relationship of STS Operations to the entire Space Transportation System budget in both fiscal year 1981 and fiscal year 1985. STS Operations represented 9 percent of the Space Transportation System budget in fiscal year 1981, a year in which the development effort was still a major factor, i.e., preparation for conducting the orbital flight test program. Initial Operating Capability is planned for the end of fiscal year 1982; and the STS Operations proportion of the budget will have increased to 61 percent in fiscal year 1985. The elements of STS Operations in fiscal year 1985 as described in Part II, above, for 1981 are as follows:

	Percent
Shuttle operations	93
Spacelab operations	2
Upper stage opertions	4
Payload support operations	1

A further breakdown of the subelements of Shuttle Operations is as follows:

	Percent
Orbiter hardware support	7.6
Crew equipment	1.9
Main engine	3.9
Solid rocket booster	20.7
External tank	20.9
Propellants	1.4
GSE spares	1.2
Flight operations	17.6
Launch operations	17.8
Total	93.0

Question. What is the current and projected annual production capacity for the external tank (ET)? What flight rate would this support?

Answer. Currently, we have a facility and tooling production capacity of 10–12 external tanks per year. Present planning calls for Construction of Facilities (CoF) and tooling investments to attain a production capacity of 24 units per year by mid-fiscal year 1987 in order to support a 24-year flight rate by fiscal year 1988.

With further facility/tooling investments, the flight rate capability can be increased beyond the 24-per year.

Question. What is the current and projected annual production capacity for the solid rocket boosters (SRB)? What flight rate would this support?

Answer. Currently, we have a facility and tooling production capacity of 8–10 solid rocket boosters (SRB) per year. Present planning calls for Construction of Facilities (CoF) and tooling investments to attain a production capacity of 24 sets per year by mid-fiscal year 1987 in order to support a 24-per year flight rate by fiscal year 1988.

With further facility/tooling investments, the flight rate capability can be increased beyond the 24-per year.

Question. What is the production rate for orbiters that current facilities could support?

Answer. The orbiter production program is currently scheduled on fifteen month centers. The existing production deliveries will be maintained on fifteen month centers assuming adequate funding availability. The maximum production rate is limited by Rockwell International tooling and is one vehicle delivery every twelve months assuming adequate funding.

If permitted to procure a batch buy for Orbiters 105, 106, and 107, based on lead time away funding availability, they could be delivered on twelve month centers.

Question. What production rate for the main engines would current facilities support?

Answer. The Space Shuttle main engine fabrication effort is not presently facility constrained. Current facility production capacity is approximately six engines per year assuming adequate funding. Engine assembly completion dates are in support of the orbiter production schedule outlined above. A smooth production flow of three new engines per year is currently being funded which supports a flight rate of 32 flights through fiscal year 1985, with a maximum flight rate of 24-per year thereafter.

Question. What has been learned from STS–1 and STS–2 that you see unexpectedly affecting Shuttle operations, such as turnaround time?

Answer. STS–1 and STS–2 experience has been very encouraging. These test flights have not resulted in any unexpected impact on Shuttle operations and the results have confirmed that the ultimate goals of the Space Shuttle operations era are achievable. The entire Space Shuttle vehicle and all supporting ground facilities have performed extremely well. The orderly expansion of the Space Shuttle's operational envelope is progressing as planned.

There have been relatively few anomalies for a program of the complexity of the Space Shuttle. The few anomalies experienced have been and are receiving intensive program management attention. Most have been corrected; some of the STS–2 anomalies remain under investigation.

The most significant STS–1 anomaly (SRB ignition overpressure) was corrected by launch facility modification prior to STS–2. The thermal protection system (TPS) damage experienced on STS–1 was significantly reduced on STS–2. The fuel cell and auxiliary power unit (APU) problems on STS–2 are expected to be correctable with no affect on Shuttle operations.

As an example of our successful results, after STS–1, approximately 250 tiles were replaced due to flight damage. Based on the preliminary inspection results, conducted at Dryden Flight Research Center (DFRC), after STS–2, it is estimated that approximately 70 tiles will have to be replaced due to flight damage. Our experience to date indicates the thermal protection system is much more forgiving than we first expected from a flight point of view.

Question. In graphic form please present your current estimated demand for commercial Shuttle use up to the year 2000. Please include a narrative of what the major assumptions are to support the demand curve.

Answer. The projected demand by non-Federal customers for Space Shuttle services through the year 2000 is depicted on the enclosed chart (Chart B) along with other principal users. The projections are based on a reconciliation of many data acquired through special studies by a variety of independent sources; namely, the Battelle Memorial Institute, the American Institute of Aeronautics and Astronau-

tics, Future Systems Incorporated, Rockwell International and the NASA Office of Space and Terrestrial Applications.

Common within each of these studies is a greatly expanding foreign and U.S. commercial communications market. In this area, projections of Shuttle demand by the year 2000 are as high as 19 Shuttle launches with the nominal peaking at about 12 Shuttle launches. The placement of transponders on orbit forecasted for the U.S. domestic and U.S./foreign traffic combined are illustrated in the companion chart. It should be noted that there are limits to the number of transponders that can occupy the diminishing resource in geosynchronous orbit over North America. For the C-Band, saturation occurs at about 700 transponders. For the K-Band, the saturation is somewhat higher because of the arc spacing but still occurs within the projection to the year 2000 (about 2,000 transponders). However, the remaining geosynchronous arc can accommodate 4 to 5 times this number before saturation. Even though the proposed 30/20 Ghz program of NASA will alleviate the North American saturation somewhat, the condition is only temporary in an ever-expanding market. The ultimate solution lies in providing a series of well-placed geosynchronous platforms capable of expansion to meet the increasing needs of the customers. None of the studies include projections for video-conferencing that might result from world increases in energy prices.

While the preponderant use of the Shuttle by non-Federal customers is likely to be for the deployment of communications equipment, Shuttle flights will be needed to service other areas such as materials processing, earth surveys for mineral deposits and land use management, new technology development and other unforeseen applications. The joint venture between Johnson & Johnson, McDonnell Douglas and NASA in materials processing is the first major Shuttle experiment in this arena. The competitiveness of the market is borne out by the number of Small Self-Contained Payload flight requests (50 percent of over 300 requests) for materials processing. It is impossible to predict how many Shuttle flights in the future will be required to satisfy this demand but some estimates are as high as 25 percent of all the commercial flights.

It should be noted that the demand through 1986 is documented in NASA's Shuttle flight manifest and represents only a fraction of overall demand due to continued use of the Delta and Atlas/Centaur expendable launch vehicles through this time frame.

Question. Please describe the tracking ground support capability to support Shuttle Operations for all the potential prime, backup and abort landing sites.

Answer. The following matrix shows tracking and ground support capability available to support landing operations during the orbital flight test program and STS operational flights prior to the Tracking and Data Relay Satellite System (TDRSS) becoming operational in 1984:

Landing site	S-band	C-band	UHF voice	MSBLS	TACAN
KSC	X	X	X	X	X
EAFB	X	X	X	X	X
Northrup strip	(STS-1,2)	X	X	X	X
Hickam AFB			X		X
Rota NS, Spain			X		X
Kadena AB, Japan			X		X

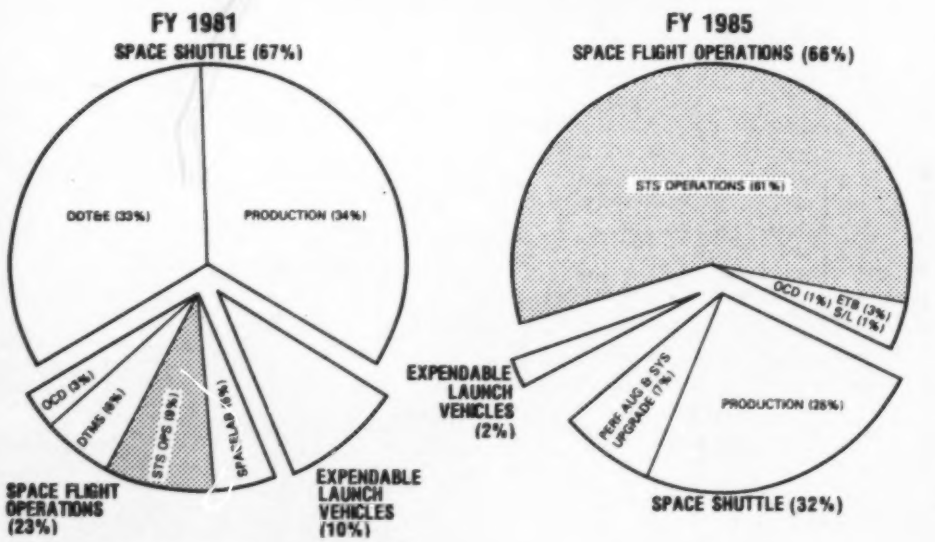
S-Band telemetry, tracking and voice data as well as C-Band radar skin track data are available to ground flight controllers at the Johnson Space Center (JSC) when STS landings occur at Kennedy Space Center (KSC) or Ellington Air Force Base (EAFB). Similar capability was available at Northrup Strip through STS-2; however, a recent change to a 28.5 degree inclination launch for STS-4 established a mandatory requirement for S-Band coverage from Dakar, Senegal. Until the TDRSS is operational, all 28.5 degree inclination launches would experience a gap in S-Band coverage during ascent phase from loss of signal at Bermuda to acquisition of signal at Hawaii. To accommodate the Dakar requirement, Tula Peak S-Band equipment was removed following STS-2. That action was deemed to be the most economical approach as procurement of new equipment was too costly and delivery times uncertain. Provision of S-Band telemetry, voice and command coverage at Dakar will enhance crew safety by providing coverage for anlysis of initial orbital maneuvering system burn data and provide for crew updates in the event of transatlantic abort or abort-once-around cases.

Loss of the Tula Peak station will mean some reduction in data if we have to land at Northrup Strip. However, metric data will be available from White Sands and surrounding area C-Band radars, and if required, UHF voice contact can be relayed through the White Sands tower. The only loss will be that of S-Band telemetry, voice and command. None of the other contingency landing sites (Rota, Kadena or Hickam) has S-Band telemetry, voice or command capability. We will incur some risk on STS-3 in possible data loss, in the event of a backup landing at Northup Strip, but this risk is acceptable in order to achieve the Dakar readiness needed for STS-4.

The Microwave Scanning Beam Landing System (MSBLS) and Tactical Air Navigation (TACAN) system provide the orbiter with accurate positioning data which enables the onboard navigation systems and crew to perform safe landings.

Once the TDRSS becomes operational (1984), telemetry and tracking data will be available to support landings at all potential sites. At that time, the requirement for S-Band and C-Band from present ground stations will be reduced to launch and landing and backup support only. In addition to assessing positioning/tracking system needs, the requirement to maintain contingency landing sites will be periodically reviewed.

COMPARISON OF SPACE TRANSPORTATION SYSTEM BUDGETS FY 1981 vs FY 1985



OCD – OPERATIONS CAPABILITY DEVELOPMENT
DTMS – DEVELOPMENT TEST MISSION SUPPORT
ETB – ENGINEERING TECHNICAL BASE

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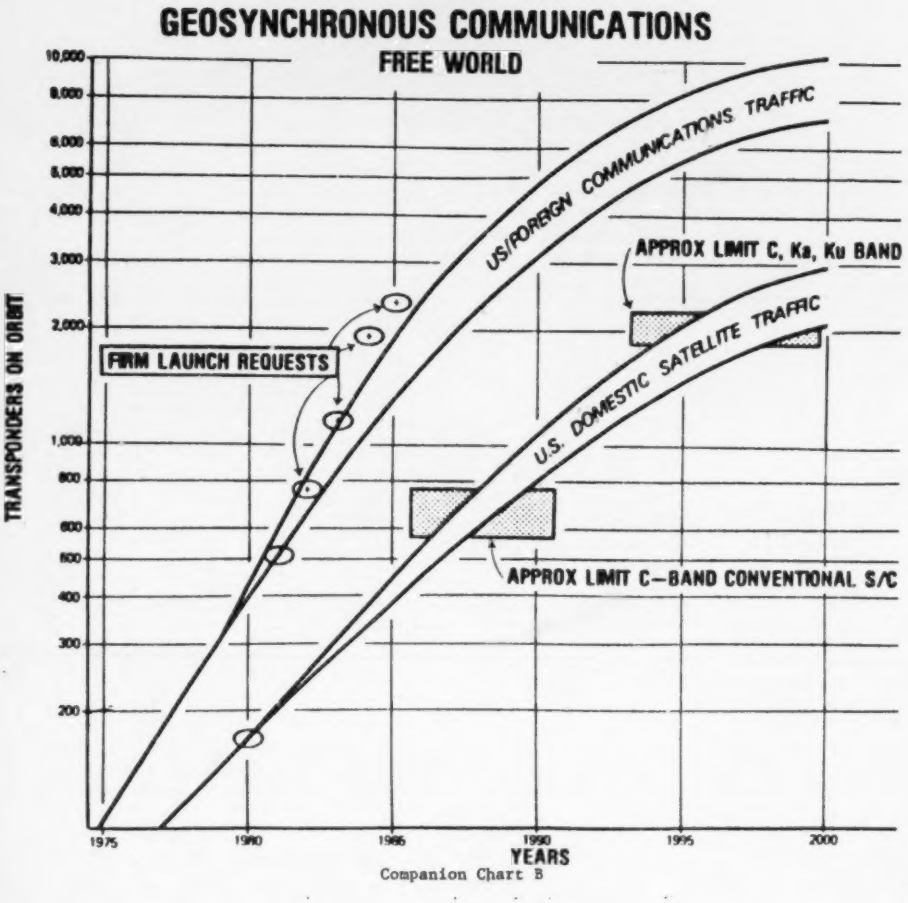
Chart A

SPACE SHUTTLE PROJECTED DEMAND MODEL

[Fiscal year]

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Kennedy Space Center:																			
NASA		4	4	5	5	5	8	9	9	8	10	8	9	10	11	13	15	17	19
Other civil government						1		1		1		1		1	1	1	1	1	1
U.S. commercial	1		2	3	3	2	3	3	4	4	4	5	5	6	6	6	7	7	7
Foreign		1	1	1	2	3	3	3	3	3	4	3	4	3	4	4	5	5	6
Department of Defense			2	4	5	5	5	8	11	12	9	11	10	10	10	10	10	10	10
KSC subtotal	1	5	9	13	15	16	19	24	27	28	27	28	28	30	32	34	38	40	43
Reflights						1	2	2	2	2	2	2	2	2	2	2	2	3	3
Kennedy space center total	1	5	9	13	15	17	21	26	[illegible]	30	29	30	30	32	34	36	40	43	46
Vandenberg Air Force Base:																			
NASA							3	2		2	3	2	3	3	2	3	4	3	3
Other civil government							2	1	1	1	2	2	2	2	3	1	2	3	2
U.S. commercial													1	1	1		1	1	
Foreign											1	1	1	2	2	4	1	1	3
Department of defense					2	6	3	6	9	8	6	8	7	7	7	7	7	7	7
VAFB subtotal					2	6	8	9	10	11	12	13	14	15	15	15	15	15	15
Reflights							1	1	1	1	1	1	1	1	1	1	1	1	1
Vanderberg Air Force Base total					2	6	9	10	11	12	13	14	15	16	16	16	16	16	16
Mission model total	1	5	9	13	17	23	30	36	40	42	42	44	45	48	50	52	56	59	62

Chart B



STS OPERATIONS

Question. Approximately what growth rate has been experienced in the launch requirements of foreign countries in the past few years? What do you expect to see in the next 10 years with regard to the foreign user market?

Answer. The number of foreign payloads launched per year by the United States from 1977 through 1981 was as shown below:

	Payload
1977	10
1978	7
1979	1
1980	1
1981	4

It is not possible to define a trend in launch requirements from these figures. 1979 and 1980 were relatively lean years for foreign payload launches, perhaps because launch requirements were postponed in anticipation of the Space Shuttle becoming operational (with significantly reduced launch costs).

The range of estimates from the continuing Battelle Institute study for NASA of demand for launch services (as of May, 1981), as well as an in-house estimate made by NASA's Office of Space Transportation Operations, are shown below:

	1982	1983	1984	1985	1986	1987
Payloads Battelle:						
High	16	13	23	21	28	17

	1982	1983	1984	1985	1986	1987
Low	11	8	14	20	11	20
High	11	14	13	16	21	20

At least through 1987, part of U.S. reimbursable cooperative launch services will be provided by expendable launch vehicles. Some payloads (for example, Spacelab D-1 for the Federal Republic of Germany) are STS-specific, but most will be open to competition between Ariane and the STS or U.S. expendables.

For the period 1988-1992 estimates are much more speculative. The Battelle estimates in the following table project added growth in most foreign space activity areas, but also assume that certain technological trends will act to reduce the number of payloads required to meet user demand. However, such payloads would probably be larger than the current norm and require additional Shuttle launch capacity.

	1988	1989	1990	1991	1992
Battelle:					
High	24	20	23	18	22
Low	13	7	13	12	12

Question. In what area or areas do you expect to see the largest growth in launch service demand?

Answer. In the near term, launch service growth demand is predicted to come from two principal areas: communications services and, in the late 1980's and the 1990's, low orbit operations for industrial purposes.

It is clear that the launch demand for communications satellites will continue to grow beyond even the most optimistic projections of the past 2 or 3 years. Recent experience with communications customers for Shuttle and expendable launch services indicate direct broadcast satellites for domestic commercial and foreign users will dominate this field.

In the area of industrial operations in space, there is an indication from the interest demonstrated thus far that successful materials processing prototype efforts will lead to serious entries into space by several large corporations. The rate of growth in this industrialization will depend on the demonstrations currently planned as well as the costs to reach orbital mission durations necessary for processes under consideration.

Question. How do you demand curves fit with those studies done outside of NASA? (i.e. AIAA and industry).

Answer. NASA consistently opted to project launch demand of the non-Federal sector conservatively compared to independent assessments of the same sector. The AIAA and industry estimates demand between 15 and 25 equivalent Shuttle flights by the mid-1990's. NASA, on the other hand, projects this same demand to require from 12 to 15 equivalent Shuttle flights.

Our assessment assumes a slower buildup of industrial usage and does not include major NASA initiatives which might require resupply of low-earth orbit platforms on this period.

Question. With regard to your demand curves, what do you see as causing the major perturbation of those curves?

Answer. Major perturbations to the NASA demand curves could come from significant increases in the demand beyond 1987 arising from involvements by the industrial sector, major low-earth orbit space station program and increased use of space by the DoD.

The first could be a large-scale increase in video conferencing demands motivated by a world price increase for energy resources. The cost of travel may be such that the economics will vastly favor video conferencing as an alternative. NASA is already experimenting with video conferencing methods between the field centers and Headquarters for its technology reviews which generally host a large audience. Broad national acceptance of video conferencing methods will impose a demand increase in the number of transponders in geosynchronous orbit.

The second perturbation could arise from successful demonstrations of low-earth orbit platform operations. Operations with several platforms using the Shuttle as construction, maintenance and logistics vehicles open the door to a number of appli-

cations heretofore unavailable. Most important is the industrialization aspect for materials processing and consumer goods manufacturing. Also of importance could be Shuttle-tended platforms for national defense purposes.

Liberal expansion in these areas would lead to increases in Shuttle flight demands of about 4 to 6 per year for communications and about 6 to 8 per year for platform operations.

Question. Do you feel NASA's current program plan maximizes the use and capabilities of the Space Shuttle? If not, what might be done to maximize our investment?

Answer. The current program plan includes demonstration over the next 2 years of most of the attributes promised for the Space Shuttle since its inception over 10 years ago. With only two development test flights, the Shuttle has evidenced the benign environment to the user that has been anticipated and launch loads are lower than predicted.

The Shuttle's virtues as an orbiting workbench have been demonstrated to a limited degree already by the STS–2 mission, and NASA plans to demonstrate its capability as a repair or servicing base by retrieval and repair of partially disabled systems on the Solar Maximum spacecraft in FY 1984. By flight thirteen, nearly all the current user mission types will have been accommodated. These missions include six payloads for SSUS–D communications customers, three IUS payloads, two DoD operational flights, two Spacelab module and pallet payloads, one large scientific free-flyer, 15 small self-contained payloads and one repair mission.

This demonstration phase will accelerate usage of the Shuttle. Shuttle operations must be able to keep pace with the demand growth.

It is anticipated that the near future will see justification of the facilities and tooling investments to increase production of tanks and SRB's above the current 24 per year rate. In addition, a fifth orbiter may be necessary to make possible protection of an expanding system against potential attrition.

Question. From a technical standpoint what have been the significant factors in reducing the flight rate?

Answer. Significant factors leading to reductions in flight rate capability of the Shuttle are:

a. External Tank (ET) and Solid Rocket Booster (SRB) production rates: NASA budget limitations have made it necessary to scale back the rate at which ET's and SRB's are produced. Further, the planned expansion of production rates to meet longer term, higher flight levels has been delayed.

b. External Tank insulation requirements: At present, considerable time is spent in hand-fitting insulated panels to the ET. It is anticipated that further flight experience may lead to less exhaustive techniques for applying insulation and, in some areas, elimination of the insulation altogether.

c. Safety constraints on processing such as component stacking in the Vehicle Assembly Building (VAB): At present, increases in time for SRB stacking in the VAB are due to safety regulations which require the evacuation of personnel during stacking operations or limiting operations to second and third shifts. Alternatives have been examined and an auxiliary facility is under review to reduce this bottleneck.

d. Increased turnaround time. Although the turnaround time between launches has increased over earlier predictions, much is attributable to reconfiguration of the orbiter to meet the variety of user payloads to be carried on successive missions. A number of standards need to be assessed that will minimize this reconfiguration time

In summary, while some of the decreases in flight rate are attributable to items that can be resolved by procedural changes, there are others that will require investment beyond current budget constraints including development fixes and possible facility augmentations. The most critical threat to flight rate appears to be the bottleneck in the VAB and facility-limited poroduction capacity.

Question. What is the most manpower intensive subelement of operations?

Answer. The most manpower intensive subelements of the Space Shuttle Operations are at the Johnson and Kennedy Space Centers. The Marshall Space Flight Center subelements are production oriented to deliver External Tank and Solid Rocket Booster hardware.

The Johnson Space Center's most intensive subelement is Mission Operations. This includes the Mission Control Center, flight control, astronaut training, flight planning and mission analysis support functions. Orbiter readiness support covering avionics, flight software, communications and systems verification is the second most intensive subelement.

The Kennedy Space Center's most intensive subelement is Shuttle Processing involving orbiter reservicing and External Tank and Solid Rocket Booster stacking and integration. Cargo integration covering interface verification and loading is the second most intensive subelement.

Question. What changes might we expect to see in astronaut training from the development phase to operations?

Answer. We expect that astronaut training from the development phase to the Operations Era can achieve approximately a 25 percent reduction in simulation training for a first flight astronaut pilot. This reduction is accomplished due to standardization of procedures and reduction in requirements for pilot developmental tasks. Starting with the operations phase, we will commence to re-assign astronauts to flights allowing an astronaut to fly up to three flights per year. We expect that with this experience carry-over, an astronaut in preparation for re-flights can be trained at a level equal to approximately 30 percent of the simulator time required for a first time pilot.

Senator SCHMITT. We want to talk with the Department of Defense and those in the private sector who are the ultimate beneficiaries of the utilization of the Space Shuttle.

Thank you, gentlemen. The hearing is adjourned.

[Whereupon, at 12:08 the hearing was adjourned.]

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